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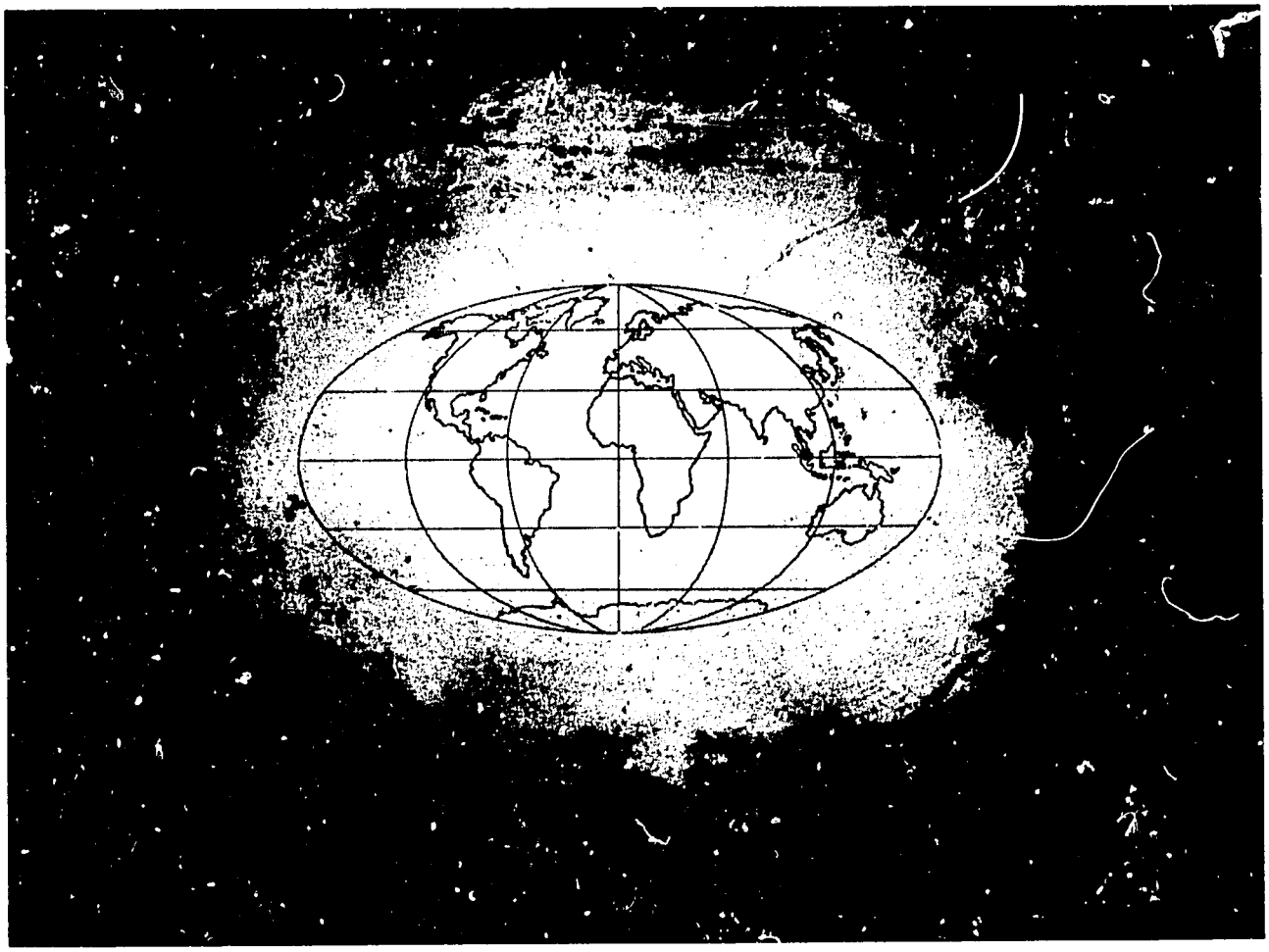
PROCEEDINGS INTERNATIONAL CONGRESS

"Research for the Potato in the Year 2000"



TENTH ANNIVERSARY
1972 - 1982

INTERNATIONAL POTATO CENTER (CIP)

FRONT COVER

Tuber of Yungay variety, a relatively high yielding variety with tubers of excellent table quality and slightly yellow flesh, bred from a double cross of *Solanum tuberosum* ssp. *andigena* x ssp. *tuberosum*, widely grown in Peru.

The world map superimposed on the tuber suggests the international representation of attendees at the congress as well as CIP's involvement in international agriculture relating to the potato.

Proceedings of the
International Congress in
Celebration of the Tenth Anniversary
of the International Potato Center
Lima, Peru
22–27 February, 1982

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"Research for the Potato in the Year 2000"

Edited by W. J. Hooker

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Preface

Photographed at the opening ceremony of the Congress (Foreground left to right) Mrs. and Dr. J.L. Thomas, chairman of the CIP Board of Trustees; President Belaunde Terry, President of Peru; Dr. R.L. Sawyer, Director General of CIP; and Mrs. Sawyer.

Preface

"Research for the potato in the year 2000", was the theme for the Congress in celebration of the tenth anniversary of the International Potato Center (CIP). The Congress was sponsored jointly by the Potato Association of America, the European Association for Potato Research, and CIP. Over 226 scientists and administrators of agricultural programs from 47 countries were present. These with CIP personnel as well as scientists from the Peru Ministries and the National Agricultural University totalled over 300 persons active in potato improvement. At no time previous, has a group been assembled which included such a broad representation of persons from countries in which potato culture results from long established, well tested practices to countries to which the potato has only recently been introduced.

Invited papers by recognized world authorities in potato production, utilization, and improvement research were presented in the plenary, (morning) sessions. These served to orient subsequent discussions with over 120 research papers presented later in each of the three days in three concurrent sessions per day. Reports include information from countries in which potato is now becoming an increasingly important food as well as from those countries in which potato has long been an staple food and its culture a high production technology science.

The tenth anniversary of CIP marks the induction in July 1972 of the International Potato Center as the fifth center of the Consultative Group for International Agriculture (CGIAR). More than a year earlier work of the Center had been initiated by an agreement with the Peru Ministry of Foreign Relations and the North Carolina State University. The Congress marked the occasion for extending the agreement between the government of Peru and CIP to the year 2000.

President Fernando Belaunde Terry of the government of Peru participated in the inauguration ceremony and invited 50 members of the Congress to visit the palace. The interest of President Belaunde in CIP's program has been enthusiastic and most encouraging.

Since experts from around the world were present in Lima, five one-day planning conferences were held for orienting CIP's programs of integrated pest control, production of potatoes from true seed, potato production in the hot-humid tropics, and strategies for late blight, virus, viroid, and mycoplasma control.

W. J. Hooker

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Plenary Session Papers

Dr. Glynn Burton, Chairman of the Program Committee of CIP Board of Trustees, addressing the Congress at one of the Plenary Sessions.

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THE POTENTIAL OF THE POTATO AS A WORLD FOOD

M. S. Swaminathan and R. L. Sawyer
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Hunger and malnutrition have been with mankind since the early days of civilization. A vicious circle exists amongst the four factors: health, food, income, and population. Medical advances to control disease increase the population and the problem of adequate food supply. Adequate food and nutritional balance tend to increase the population and consequently the food requirement. Increased income produces a greater demand for food and a further drain on food supplies. Increased income produces a greater demand for animal meats and creates a greater demand on plant foods for animal feeding at the expense of the supply available for human consumption.

There has been no planned attack on this vicious circle up until now. Nutricionists have fought for programs to provide a better balanced diet. The medical profession has made consistent advances in the elimination of major diseases and pests of mankind. Agriculturists have consistently made major advances in food production, concentrating mainly on the traditional cereals which come in a concentrated, well packaged form at harvest for preservation and distribution. Raising the incomes of the "poorest of the poor" and population control programs have been goals of many major international funding sources for many years. The approaches have been reactionary to problems on a piece meal basis with insufficient long range planning and consideration of all alternatives and interactions.

A long range plan for an adequate food supply in the world must involve many factors but principally amongst them are:

a. An adequate program in population control.
b. An adequate investment in agriculture with a well coordinated research and extension base.
c. An adequate pool of professionals to plan, execute, and implement programs.
d. Time to cope with cultural and religious mores.

All alternatives must be considered and innovative approaches developed which may require a planned attack on tradition when it is impeding progress towards the goal of an adequate diet, good health, and productive happy lives for all mankind.

This Congress encompasses many of the components necessary to a strategy for an adequate world food supply. It involves long term planning - to the year 2000 - with a crop that is well balanced nutritionally, but a non-traditional crop for attacking the world food problem. Furthermore, this Congress is considering non-traditional approaches to the production of the potato and the research being accomplished to eliminate factors which have prevented the use of the potato in many climates up until now.

To plan for the potato in the year 2000 requires an objective assessment of the potato as a world food at the present time. What is the present status of the potato in relation to several major requirements for a world food?

Nutritional balance

There are a wealth of statistics available from many sources indicating the comparative advantages nutritionally of the potato over all of the major world foods. The balance of proteins to calories, the balance amongst the more important amino acids in the protein, and the levels and spread of minerals and vitamins make the potato second only to eggs in nutritional value as a single food source.

As new varieties are produced with higher yields and better resistance to pests and diseases, care must be taken and monitoring must be done to make sure that an already excellent product is not harmed. There is adequate variability amongst breeding materials to increase the protein to calory ratio if the normal mix of foods being utilized by a country indicates this would be valuable. However, present judgement of senior management at CIP is that it would be detrimental to the nutritional balance of the potato to try to build in a higher protein content as is being done with a number of the major cereal crops.

Climatic flexibility for production

The potato has been mainly a cool season crop for the higher altitudes in the tropics where it originated or for northern latitude cool climates for which it has been highly adapted by scientists during the past 150 years. A few of the varieties developed for northern latitudes have had some flexibility for warmer climates.

With the establishment of CIP and its world potato collection with facilities in the high jungle and the lowland Amazon basin, the ability to screen for hot climate flexibility in the tropics has increased tremendously. CIP with its associated contracts has developed and identified material with cold resistance to -8° and other genotypes which will produce edible tubers in a very short period in the hot-humid tropics. The genetic flexibility for growth has been identified more rapidly than has agronomic research been conducted for potato growing in such environments. However, during the past two years, CIP has consistently produced 15 tons of potatoes per hectare in 60 days using commercial non-adapted varieties at its Yurimaguas low jungle facility. This indicates that good progress is being made on the agronomy for tropical potato production.

A tremendous genetic reserve for flexibility to climates exists. Use of this has only recently been initiated. The extent to which resistance to diseases and pests of the lowlands or their control will have to be developed will only be known after there has been a pressure established from continuous potato production over a period of years in such locations.

Comparative advantages in the use of land, time, water, and energy

The potato produces more well balanced protein and more calories per unit area per unit of time than any other major plant food. Although it is a high investment crop, returns are very high in relation to the investment. Statistics from a number of developing countries in the tropics indicate that the potato produces a higher return to the grower per unit area than any other crop. Obviously, part of this is due to the high cost of potatoes on the market and the high demand for this commodity known mainly as a luxury vegetable in many tropical countries. Even at 5 tons per hectare in Ethiopia, the potato is the best economic plant crop for small farms in the highlands.

Potential for genetic improvement

The potato has been developed for northern climates utilizing a very narrow genetic base. CIP's world collection of native cultivars and wild species which has been developed over the past few years with the collaboration of many institutions is a resource whose use has only recently been initiated. A major portion of the tuber bearing wild species have not been used up until now in breeding programs. Their potential value is still unknown. It will be long after the year 2000 before the variability which exists with the potato will have been utilized to a similar level as the major cereal crops. Thus, there is tremendous potential for exploitation in the potato which could give wider climatic flexibility with higher yields and better resistances to pests and diseases.

Seed production

Good low cost seed has been one of the major limiting factors for use of potato as a food in tropical climates up until now. Most tropical countries are presently relying on costly importations from northern latitude countries as the base for potato production. Seed costs are from 50 to 75% of the total production costs under such conditions.

The systematic study on the inter-relationship of the climate to pest (vector) avoidance has helped in the realization of low cost healthy seed production in developing countries such as India. The experience in India in the last few years has proved that the use of "seed plot technique" by the small farmers can enable them to produce a reasonably healthy seed crop at low cost as well as allow them to sustain reasonable yields. In the developing countries producing potato, the extension and/or modification of the Indian system will be useful to identify suitable areas for potato production. Selection should be where climatological factors allow the required period for potato production as well as avoidance of vector populations. This will provide a solution to the production of low cost high quality tuber seed and reduce or eliminate dependence on seed imports.

CIP has made major research advances in the past three years in identification and incorporation of resistance into advanced breeding lines for those viruses important to seed production schemes.

The highest priority research at CIP this past few years has been the development of technology which could permit production of the potato from seed instead of tubers. This change from the traditional methods could well be the greatest break-through in agriculture this century. The Chinese through necessity for food have already commercially established the viability of certain variations of this technology. CIP will have this technology at an advanced stage in growers fields with national scientists well before the year 1985.

Post-harvest technology

Appropriate and efficient post-harvest technology and marketing are critical to the entire production-use system of potato due to its bulkiness and perishability. Post-harvest losses are highest throughout the developing world and it is usual that in areas with seasonal peak production, potatoes are available for consumption only during a part of the year due to the inadequate storage. Unlike in temperate regions, in tropics and sub-tropics the potato crop is harvested at the time when summer sets in, and temperatures are high during post-harvest handling and marketing, leading to deterioration in storability and consumer quality. It is therefore, necessary that priorities be developed for making available low cost renewable energy dependent, storage and processing systems.

Southern and eastern Asia, which have 50% of the world's population, only possess 16.5% of the world's energy resources. If China is excluded the position becomes 30% of the world population vs 3.2% of world's percentage of energy resources. Such severely energy limited areas need urgently, processing and refrigeration systems based on renewable energy sources such as solar photovoltaic techniques and bio-gas.

The reduction of spoilage as well as proper utilization of the potato, needs involvement of institutions like Home Science Colleges with the extension programmes which would be needed in the developing countries. Indian experience of "Lab to Land" programme involving direct dialogue between scientists from different disciplines with the small farmers has brought out the efficacy of such a system for the speedy translation of research results in a usuable package by the small farmer towards increasing his production potential as well as for the integrated up-liftment of the farming community.

The potato and farming systems

What has taken place in India during the past 25 years, clearly demonstrates how well the potato fits into cropping patterns. No third world country has made as rapid increases in use of the potato as a food as has India.

For many years India depended mainly on two cereal crops, rice and wheat, to feed its people. Both crops had to go to complete maturity and could be grown during the same 356 days in the same fields. There was approximately an additional 80 days a year which could produce food on the same land. The potato was the flexible crop which fitted into the farming system and quickly became a major crop for India. The potato did not need to go to maturity since it is the tuber and not the seed which is eaten. Maturity for the potato could be when the rice crop had to be planted.

There are hundreds of thousands of hectares of potatoes in the southern hill country of China which fit into the farming system in a different manner than in India. In southern China the potato is intercropped with a number of other food plants, principally corn and soybeans, with staggered plantings. The Chinese claim that this system gets the most from the soil, the light and the crops on a combined basis.

Thus the potato already has demonstrated its flexibility to fit into farming systems in a few tropical areas where the potato has become important as a staple food. Still to be investigated is the role of the potato in farming systems for the rest of the tropics where the potato is still mainly a luxury vegetable.

Acceptability of the potato as a food

According to FAO statistics, the potato has had the greatest increase in production in third world countries of any major world food crop during the past ten years. These statistics certainly attest to the acceptability of the potato as a food and the increasing awareness of the productive capabilities and the food value of the potato in developing countries. South Korea in its new five year plan is concentrating on potato production at the expense of rice, its traditional crop, in order to give a better stability to its annual food supply. India is another good example of a country which was traditionally a rice-wheat consuming nation that has found ready acceptability of the potato.

A social scientist at CIP has been studying the acceptability of the potato as a food in a number of countries around the world which are not traditionally consumers of potatoes. The study still in process indicates that acceptability and use of the potato as a food depends primarily on price and not on food habits or customs. Thus the ability to lower the price to the consumer so that the cost of the potato per unit of food value is similar to other inexpensive foods is important for the technology being produced for the potato in the year 2000.

Forum for national policy makers

The major barriers to expanded and sustained potato production as well as its utilization are at the national level. This calls for national, regional, and international coordination among the policy makers for devising a package of public policies suited to the respective national needs for stimulating and sustaining potato production and utilization. Such a package of policies could be devised towards streamlining each component of the production system in different ecological and socio-economic environments with a definition of national priorities for potato vis-a-vis other crops, including pricing and movements from the area of production to consumption. The introduction of potato in "Food for Work" programmes will help in establishing its rightful place in elevating the nutritional standards of the rural and urban poor.

The much needed coordination among the policy makers from developing countries for crystalizing the package of policies can possibly best be achieved by providing a common international forum at seminars or panel meetings under the auspices of CIP/FAO. Such periodic dialogues among the policy makers, should be based on case studies of successful examples of removing the barriers to expanded and sustained potato production and utilization.

Summary

On a global base the potato already is a major world food occupying fourth place in importance, falling just after the three cereals rice, wheat, and corn. However, most of the importance of the potato as a food exists in the colder regions of the world, either the highland tropics or the northern and southern latitude temperate climates.

The genetic potential which exists with the potato must be utilized to the fullest extent for the tropical regions where a major portion of the world population exists with insufficient diets and no adequate staple food supply.

The major cereal crops have been highly exploited for many years. The resources with the potato have only recently been developed which would permit a similar kind of genetic exploitation as has taken place with the cereals. Already the flexibility of the potato to environment is emerging.

Technology is being developed which will give exciting new approaches to production, storage, and processing for tropical regions of the world. National capabilities for research and transfer of technology in agriculture are rapidly being developed in a number of tropical countries. Good national agricultural capabilities in research and transfer of technology are essential to the development of the potato for tropical climates.

With coordination of research effort and a concentration on the priority factors which have until now limited the use of the potato, the potato will take its proper place as a world food by the year 2000. This Congress provides a needed base for action to exploit the potential of the potato.

THE POTATO IN THE LOWER TROPICS

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Introduction

The potential of the potato (Solanum tuberosum) as one of the most efficient food crops is an accepted fact. Besides being a highly nutritious source of food with high quality protein, over twice as much dry matter and calories can be produced through potato production on unit area of land and time, as compared to wheat or rice. Talburt and Smith (1967) have rightly observed that nature has designed only a few foods that are capable of nourishing mankind and of these, the potato is one. The potato ranks first in protein production per hectare per day. Biological value, which is an index of the portion of absorbed nitrogen retained in body for growth or maintenance, or both, is 73, compared to 54 for maize and 53 for wheat flour (Kaldy, 1972). It is for this reason that in recent years several authorities have indicated an important role for the potato as a food crop, particularly in the developing countries of the world and where protein availability has been showing a downward trend (Simmonds, 1971; Dodds and Hawkes, 1952; Hay and Allen, 1978; Swaminathan, 1977).

In the last 17 years the population of the developing countries increased by 50% while the total increase of the world population was 40%. For the developed countries it was only 16% (Table 1).

For the same period, the per capita potato production decreased by 25% for developed countries but increased 69% for the developing countries (Table 2). This clearly shows the growing importance of the potato as a food for the populations of the developing countries (Table 3).

To achieve the foregoing changes in potato production, technology for the developing countries is needed in order to increase potato yields, which in the developing market economies is about half (10.5 t/ha) of the developed ones.

In the specific case of Brazil, the population growth index is much higher in the Western and Northern regions and potatoes must be transported from 1000 to 3000 km. to reach only the wealthier portion of the consumers.

The production of the potato in the lower tropics is a recent innovation. Nevertheless, the primary centre of origin of the cultivated potato is the tropics, between 10°N to 25°S and at altitudes of 2,700 to 4,200 m. (Hawkes, 1941). The potato defied adaptation in the lower altitude tropics, mainly for socio-economic reasons. However, in recent years, there have been definite trends in its acceptance as an important article of basic food (Figure 1). From an ecological point of view, the lower land tropics, to quote Mendoza and Estrada (1979) and Wellman (1969), are zones at elevations between sea level and 1,000 m with day length varying between 12-13 hours; average light intensity between 8,000-9,000 fc; absolute maximum temperatures in the range of 35 to 40°C and absolute minimum temperatures between 20 to 22°C, with mean temperature of 25°C or more. Annual rainfall is 2,000 to

Table 1. Population growth rates by world regions.

Region	Populations x 1000		
	1980	1963	Percent change in population 1961 - 80
World	4414800	3160294	39.7
Developed market economies	785805	673934	16.6
North America	246100	208200	18.2
Western Europe	372123	335998	10.8
Oceania	17637	13482	30.8
Others	149945	116254	28.98
Developing market economies	2213460	1448134	52.8
Africa	376912	229723	64.1
Latin America	368466	232215	58.7
Near East	217741	140913	54.5
Far East	1245210	841875	47.9
Other	5138	3408	50.8
Centrally planned economies	1415540	1038226	36.3
Asian CPE	1037600	712645	45.6
Eastern Europe and U.S.S.R.	377941	325581	16.1
All developed countries	1163740	999515	16.4
All developing countries	3251060	2160779	50.5

Source: FAO Production Yearbook 1973, 1980.

Table 2. Per capita potato production and percent change in production: by world regions.

Region	Per capita production 1978 Kg.	Percent change production 1961/65-1980
World	66	-15
Developed market economies	100	-24
North America	79	12
Western Europe	143	-34
Oceania	60	49
Other	29	- 2
Developing market economies	15	93
Africa	9	119
Latin America	32	40
Near East	26	132
Far East	9	150
Other	2	113
Centrally planned economies		
Asian CPE	14	35
Eastern Europe and U.S.S.R.	415	-25
All developed countries	202	-25
All developing countries	15	69

Source: CIP/World Potato Fact (1982)

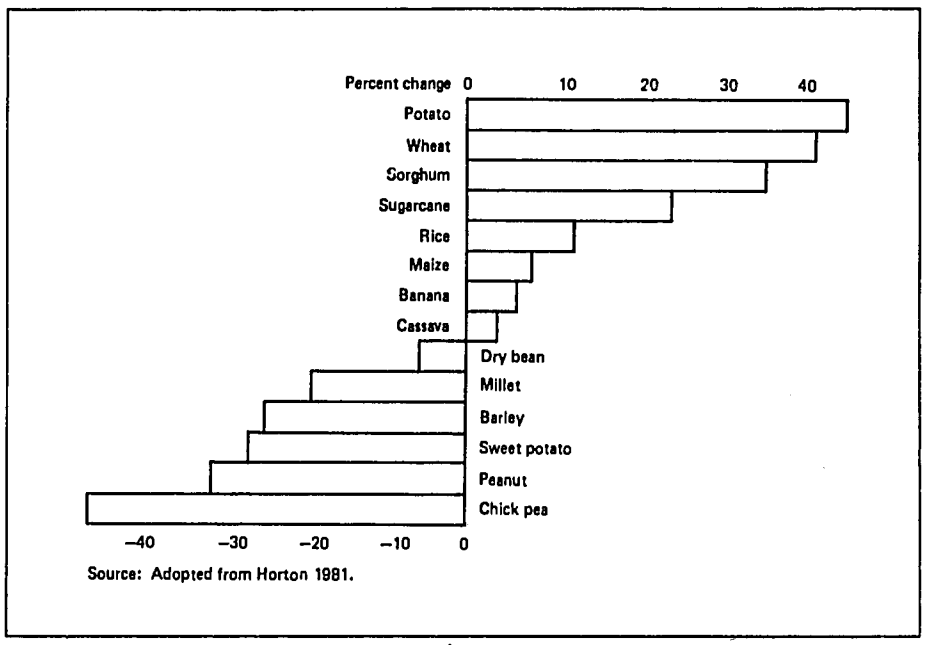

Figure 1. Change in per capita production of selected food crops in developing countries, 1963-78.

Table 3. Potato production, area, and yield by world regions, 1980.

Region	Area (X 1000 ha)	Production (X 1000 t)	Yield t/ha
Developed market economies	2,963	69,393	23.4
North America	575	16,176	28.1
Western Europe	2,165	47,838	22.1
Oceania	45	1,193	26.4
Other	178	4,186	23.6
Developing market economies	2,984	30,843	10.5
Africa	449	2,983	6.6
Latin America	1,095	10,602	9.7
Near East	422	6,385	15.1
Far East	981	10,867	11.1
Other	1	6	6.3
Centrally planned economies	12,115	125,440	10.4
Asian CPE	1,690	14,889	8.8
Eastern Europe and U.S.S.R.	10,425	110,551	10.6
All developed countries	13,388	179,944	13.4
All developing countries	4,638	45,732	9.9
World	18,026	225,676	12.5

Source: CIP/World Potato Fact (1982)

4,000 mm and the bulk of the precipitation is during summer months. Winter months are often dry. A majority of soils are characterized by low pH and high aluminum concentration, causing toxicity problems. The tropics thus, consist of the zone bounded geographically in the north by the Tropic of Cancer and in the south by the Tropic of Capricorn. The latitude is 23°27' but 30° North and South Latitudes are also generally considered part of the tropics. Sri Lanka, Eastern India, Bangladesh, the Terai plain of Nepal, a part of Burma, Laos, Vietnam, a part of China, most of Africa, all of the Central America and most of South America are within this range.

In this region, rice, cassava, sweet potatoes, some Dioscorea species, and some bean crops are the basic foods. The potato is still a minor crop mainly grown during mild winter under equinox conditions. Although the growth phase is considerably shortened and an ideal tuberization period is limited, short days and abundant sun-shine induce early tuber initiation and rapid tuber development. In Bangladesh, yields of 10.6, 14.8 and 16.5 t/ha were obtained in 60, 75 and 90 days, respectively, (Ahamad and Rashid, 1981) by using adapted varieties. In West Bengal, India, representing the lower tropics, 13.5 t/ha of potatoes were harvested in 70 days (Anonymous, 1976). In Kenya, the same yield was achieved in about half the time required for production of an equal weight of tubers under long day conditions (Moreau, 1944). In Brazil, yields of 20 to 25 t/ha are obtained during the winter months at mid-elevation altitudes, while 10 to 20 t/h are obtained during the summer, in 80-90 days. At sea level, yields of 10-15 t/ha are obtained in 70-80 days when the crop is raised during the winter months.

It is thus obvious that ecological restraints, as put forth by some scientists (Mukhatar, 1972; Kishore and Upadhya, 1977), do not present impossible barriers for adaptation of the potato in the lower land tropics.

It will not be out of place to mention that in Europe, as the literature has it, the crop was generally unimportant until the eighteenth century after its introduction in 1576. Earlier introductions from the tropics (Peru) were poor performers. It was only after improved varieties adapted to temperate latitudes were bred that the potato became established as a major food crop. In this context, major problems which have limited the potato growth in the lower tropics are mainly of a scientific and technical nature. Problems arising from socio-economic and socio-political factors have, of course, over-riding influence.

Major Problems Limiting Growth

(a) Narrow genetic base

The varieties planted in the lower tropics are from northern latitudes and do not express their full yield potential in a profoundly different environment because of the difference in day length and temperature. The classical example of this is illustrated by the data from Pushkarnath (1970). Of the collection of 642 established commercial potato varieties from temperate countries introduced into India from time to time and tested under short day condition only 6 percent gave comparable yields with local varieties and among these only 2 varieties viz Up-to-Date and Great Scot could be established in commercial culture. The same would hold for Bangladesh. Among the wide spectrum of exotic varieties, mainly from the Netherlands, most of the varieties with the exception of Cardinal, Patrones, and Multa failed to become established. In Brazil more than 100 varieties have been introduced, however, only Bintje, Achat, Baraka, and Radosa are being cultivated regularly.

Besides, genetic variability in the available cultivars is relatively narrow and most of the present day varieties do not fit into the variable growing conditions of the lower land tropics.

(b) Disease and pest problems

Major diseases of potatoes in the lower land tropics are bacterial wilt (Pseudomonas solanacearum) and viruses. Late blight (Phytophthora infestans) under cool and humid conditions as in north west Bangladesh, Sri Lanka, and Brazil is of common occurrence. Early blight (Alternaria solani) is also very important in the mid elevation regions of Brazil and Sri Lanka during the rainy seasons. Fusarium dry rot (Fusarium spp.) is considered a major problem in seed potato storage in Brazil.

Among the less important pathogens one can include Rhizoctonia solani, Helminthosporium solani, and Verticillium spp. Rhizoctonia solani, however, is proving of importance in fields established from true potato seed.

Among the pests, the leafminer fly (Liriomyza spp.) the potato "pin worm" (Diabrotica speciosa) and other Crysomelids are very important. The root-knot nematodes (Meloidogyne spp.) and potato tuber moth (Phthorimaea operculella) are a great menace.

Significantly, none of the devastating diseases of the temperate region, viz. wart (Synchytrium endobioticum), bacterial ringrot (Corynebacterium sepedonicum), and potato spindle tuber (PSTV) have been recorded. Cyst-forming nematodes, serious pests in the temperate regions, have not been reported in the low land tropics either.

(c) Degeneration of seed stocks

The key constraint to effective exploitation of the crop is inadequate supply of good quality seed. No factor is more critical to potato production than a regular supply of quality seed at a reasonable price that a small farmer can afford. At present, most of the countries have little in the way of domestic seed production. The farmers are, therefore, obliged to use degenerated stocks of local varieties; hence yields are low and unremunerative. Even the high quality imported seed degenerates rapidly because of late arrival of seed stocks. Aphids and leaf hoppers that are prevalent in earlier stages of crop growth or in the later stages towards maturity as in Bangladesh, undermine its health.

(d) Post-harvest losses and storage problems

Unlike temperate countries, in the lowland tropics the storage of this bulky perishable crop poses a serious problem. A significant percentage of the crop is lost during the post-harvest period due to high temperatures that make the harvested tubers vulnerable to several rots. Due to inadequate and inappropriate storage facilities, farmers are compelled to dispose of their produce immediately after harvest. Thus, potatoes are known as an inelastic product. This results in a temporary glut in the market, leading to low prices, and thus adversely affecting the economics of the crop.

Storage of seed potatoes in a single crop zone, requires from seven to nine months. In absence of adequate refrigerated storage, seed stocks are rendered physiologically senile due to the high losses caused by rotting, excessive sprouting, and shrinkage. Hence yields from the resultant crop are extremely low. For regions where two or more crops are grown in a year, varieties with long dormancy but responding well to dormancy breaking chemicals may help solve the problem.

(e) Crop management problems

Information on improved production techniques and cost economics of the crop is inadequate. Agronomic techniques developed in temperate countries are not directly applicable to the lower tropics, where the crop received minimum levels of tillage, fertilizer, water and other in-

puts. Plant protection measures are adopted only by a few progressive farmers. Many farmers use either small -sized tubers of local degenerated varieties, or use cut seed-pieces of imported seed to effect economy on seed cost. Post-harvest techniques are generally neglected. Cultivation of potatoes is practiced in the same fields in succession, thus aggravating the disease problems. Therefore, all these factors interact to reduce the yield. High risks and uncertain returns prevent farmers from investing in cash inputs and, the asset base of the farms remains sub-optimal from the point of view of crop management.

(f) Socio-economic factors

Despite the recognized potentialities of the potato as provider of maximum food per unit area and per unit time, it is still considered to be a luxury vegetable in developing countries. At national levels, no priorities have been determined for accelerated development programs for adoption of an institutional framework to give necessary support to the crop. The knowledge of the socio-economic conditions with respect to potato production and demand patterns is scarce. There are no production incentives for the potato as compared to wheat and rice crops in the form of subsidising prices on costly inputs and providing adequate long-term credits. There are no input-output pricing policies that can optimize the efficiency of crop production and stabilise marketing. The cost risk-return structure of farming influences the decision making of farmers on crop choice.

Major approaches for solution of problems

Most of the foregoing problems need to be solved through research to give the potato its right place in the economy of the countries of the low land tropics. To achieve these objectives, long term planning is required for effective basic and adaptive research on different aspects of the potato. Some of the essential lines of work required during the 80's are described below:

(a) Varietal improvement

Some understanding of the history of present varieties in culture in the lowland tropics is essential for projection of its national improvement. Traditional potato varieties, which are widely grown, are relics of earlier introductions, mainly descendants from subspecies andigena (Swaminathan, 1958; van der Plank, 1946). They have been since transformed, based on local adaptability to environmental factors, through sustained high selection pressure. Possibly, these cultivars also became saturated with degenerative diseases; hence not productive. To overcome this situation, there is a definite need for comprehensive research for breeding varieties to suit the agro-climatic conditions of low land tropics. The varieties should be essentially photo-insensitive and tolerant to high temperatures. Their main characteristics should be:

(1) Ability of seed tubers to survive and emerge rapidly under high soil temperatures.

(2) Quick, early, and balanced haulm growth with good leaf canopy.

(3) Inherent ability for fast tuber growth to give a high tuber to haulm ratio or high harvest index.

(4) Built-in resistance to insect transmitted viruses (PLRV and PVY), bacterial wilt, and late blight.

(5) Longer dormancy period so as to facilitate tuber storage over 7-9 months but with high responsiveness to dormancy breaking chemicals.

The first immediate step in this direction is an improvement of the domestic so-called indigenous cultivars by re-juvenating their stocks. These varieties cultivated in each area have proven adaptability to local environmental factors. Though they do not have very high resistance to diseases, they are also not very susceptible. Such an attempt would improve the present level of national yields until the new suitable varieties are bred.

Simultaneously, the hybridisation program should be initiated to produce large progenies of hybrids for selection. This would entail incorporating, into a few domestic varieties with agronomic value, a large number of desired genes consistent with the foregoing breeding objectives by a succession of crosses and subsequent selection for the most promising recombinations. For those traits with complex inheritance where environmental factors exert considerable influence upon the genotypes, population breeding (progeny testing) as outlined by Mendoza and Rowe (1977) would be appropriate. In this system, the breeding work should create a variable population with an enhanced frequency of desirable genes for adaptation, yield, and disease resistance through recurrent selection.

Choice of parents is a first pre-requisite for the success of the breeding program, especially for developing varieties meant for the warmer conditions of the lowland tropics. Earlier studies showed that wide crosses should be made to introduce genetic variability using andigena or andigena derived stocks or the wide range of variability which occurs in related wild tuber bearing Solanum spp. Khanna (1966a; 1966b) screened the progeny of the crosses (S. tuberosum x S. chacoense) for tolerance to high thermoperiods and a number of the clones gave significantly higher yield than the tuberosum varieties. Saleem and Shafi (1966) concluded that andigena varieties have more adaptability to warmer temperatures. The variety Antarqui, bred from andigena x tuberosum, was claimed to be tolerant to 18 to 24°C. In coastal areas of Kenya, CIP 377257.1 (tuberosum x phureja) gave remarkably commendable yields where the temperature regime during growing period was 22 to 27°C. Furthermore, the progeny from andigena - derived stocks are day-neutral for tuberisation (Rothacker, 1962). In Bangladesh, andigena-based tuber families for adaptation to lowland tropics were received from CIP. These involved crosses for resistance to late blight, bacterial wilt, and insect transmitted viruses. They showed predominately day neutral reaction for plant characters and tuberization. Of 1700 genotypes, more than 60 percent matured in 60-70 days.

In Brazil 17,773 genotypes belonging to 250 families from CIP were tested in 1980/1981. The crops were grown during the rainy and dry periods. Plants with good characteristics were selected at rates of 3.5 to 16.7%. Better plants and yields were observed from crosses between Solanum tuberosum, S. phureja and Neotuberosum. Promising lines were tested at mid elevations of the western part of Brazil and also in the lowlands near Rio de Janeiro and Manaus. The best clones are being increased for further tests. (Table 4).

Table 4. Summary of behaviour of CIP material in Brazil (EMBRAPA 1980/82).

Dates	Material under selection	
	Families (N°)	Genotypes for selection (N°)
01-05/80	44	1,253
04-07/80	81	2,046
05-09/80	42	4,563
02-06/81	24	2,059
09-01/81-82	59	7,862
Totals	250	17,773
Dates	Selected genotypes (N°)	Genotypes selected (%)
01-05/80	44	3.5
04-07/80	341	16.7
05-09/80	518	10.0
02-06/81	208	11.5
09-01/81-82	903	11.5
Totals	1,834	10.3

(After de la Puente and Mendoza, 1982)

It can be thus concluded that for selection of desirable lowland tropical varieties, highly heterozygous and heterogeneous populations of wide crosses hold a good future promise. Inter-specific crosses involving tuber forming species of Solanums with potential value of characters for adaptation and disease resistance are difficult to obtain owing to environmental, genetical, and cyto-genetical complications.

Most of the varieties generally do not flower in the warm climate lowland tropics. Furthermore, national programs have difficulties to run the breeding programs needed for their countries. In this context, the International Potato Center has to play a vital role in a regular supply of the segregating progenies for selection of promising genotypes in the environments of lowland tropics.

(b) Raising potatoes from true seed

Raising potatoes from true potato seed (TPS) could be another immediate possible opportunity in extending potato cultivation in the lowland tropics. This is a means of virtually starting with virus free material. It would mean taking the basic seed production program to the farmer's door step and thus providing a low risk technology because the high investment on costly potato seed is no longer a limiting factor. Use of TPS may be economical and convenient for handling and long distance transportation without any deterioration during transit and storage.

Such a technology seems to be more feasible for countries like Bangladesh where the holdings are small and the farmers have scarce resources. For example, preliminary studies in Bangladesh indicate that yields on the order of 14. 6 t/ha. have been obtained in 80 days after transplanting (Table 5). The average national yield of potato is 10 t/ha. Furthermore, many farmers in the lowland tropics are good horticulturists and they would make this technique a success. This technology also offers good rural employment potential.

Table 5. Performance of open pollinated progeny of Kufri Iyoti at Bangladesh Agricultural Institute, Dacca, Bangladesh.

Plant characteristics and yield components	Mean values
Plant height (cm)	49.9
Leaf area index	3
Foliage uniformity	excellent[1/]
Foliage weight (t/ha) (at peak growth period)	24.5
Tuber yield (t/ha)	
(i) mean	14.6
(ii) best	24.5
Yield in 3 average grades (%)	
Large (61.0 g)	14.7
Medium (23.0 g)	58.0
Small (6.5 g)	27.3
To uniformity	good[2/]
Nat potato yield of the country (t/ha)	10

[1/] 80 days after planting, comparable to the clonally propagated crop.

[2/] 80 days after planting, generally white oval tubers with shallow eyes.

However, there are some technological aspects which need to be considered before adoption of TPS on a commercial scale. Potato varieties as such may be expected to be extremely heterozygous and their progenies will contain a variable population similar to F_2 which may not be agronomically acceptable. To overcome this problem, a comprehensive research program is needed at CIP and other institutions to develop phenotypically uniform lines using monoploids and diploids. It is reported that tetraploid progeny from tetraploid-diploid or diploid crosses are uniform, vigorous, and high-yielding. Recently, phenotypically more uniform families have been developed at CIP through intercrossing followed by recurrent selection. Such lines may have a high yield potential because of heterotic effects. Chromosome engineering in production of desired lines will go a long way in producing commercially acceptable families with high yield and better disease resistance. Another important aspect is that parental lines must be identified with profuse flowering and high fertility under tropical environments. Such parental lines should possess built in resistance to major diseases of the region. Research is also called for on the pathological aspects of the crop raised from true seed both in the nursery stage and after transplanting. Some diseases such as damping-off might be problematic. Agronomical and physiological aspects of TPS in the lower tropics are also important and need to be perfected.

(c) Scientific potato seed production

As the potato is conventionally asexually propagated, its production under ideal conditions and its transportation to lower tropic regions becomes, nowadays, a very costly process. Actually, potato tuber seed shares from 40 to 60% of the total production cost in the lower tropics.

Development of sound seed production technology based on research through organized seed programs should be one of the essential pre-requisites. Seed stocks must be genetically pure and free from seed-borne diseases and should also be in the right physiological condition at planting time. The seed should also be of optimum size. No doubt ecological conditions prevalent in the lower tropics are not ideally suited for growing seed potatoes as in the Netherlands, Scotland, Germany, Canada, and other countries. Nevertheless, reasonably clean seed stocks could be raised by following the basic principles of seed production with suitable modification. The program should mainly aim at exploiting the vector-free seasons with adjustment of planting and harvesting dates, timely roguing before arrival of aphids, adoption of appropriate plant protection measures, and proper cultural methods. Of course, one of the requirements is to start with high quality planting material.

Degeneration studies in Bangladesh to test this simple methodology with six commercial potato varieties showed that initially high grade stocks could be reasonably maintained in their health up to the fourth clonal generation. In Switzerland, which is climatically not well placed for production of quality seed, its production has been made possible through indexing of initial stocks, their rapid multiplication, rigid field inspection, and post-harvest tests (Keller, 1974). Similarly in India, where seed production was restricted to the high hills on the pattern of Scotland, quality seed potatoes are now produced in vector-free locations in the Northwestern plains containing 90% of the potato area (Pushkarnath et al., 1971). Such approach seems feasible for most of the countries in the lower tropics. It would be quite unrealistic to aim at high standards as in the case of seed exporting countries. However, there are some factors to be considered in order to improve efficiency of seed production programs for lower land tropics:

(1) Survey to locate aphid-free areas and seasons based on the dynamics of aphid populations and occurrence of destructive pests and diseases.

(2) Undertaking degenerative studies to determine the rate of virus infection in the varieties in culture and periods of renewal of their seed stocks.

(3) Control of aphids and other sucking insects such a leafhoppers by cultural and chemical methods.

(4) Breeding varieties of short cycle which are not exposed to full epiphytotic periods combining field resistance to insect transmitted viruses.

(5) Standardization of seed agronomy.

(6) Study of techniques or rapid multiplication so that the number of clonal generations between the development of the first initial nucleus of stocks and production of certified seed could be reduced.

(7) Standardization of post-harvest technology to maintain the seed stocks in correct physiological condition.

(8) Standardization of post-harvest check of the seed stocks in different stages of multiplication to determine current year re-infestation in the seed stocks.

The aforesaid technology as envisioned would provide healthy potato seed at a much cheaper rate which would have a far-reaching effect in stabilizing potato yields.

(d) Post-harvest technology and storage

As stated previously, significant post-harvest losses occur in the lowland tropics because of the warm climate that follows harvesting. Countries in this region will, therefore, have to devote considerable research to standardize post-harvest technology consistent with ecological conditions. A notable work has recently been done in designing low cost non-refrigerated cool stores for short term storage of both wire and seed potatoes. But it seems equally important to control diseases and pests during storage which account for major seed decay or damage. Important diseases are charcoal rot, late blight, dry rot, brown rot, and bacterial soft rots.

Among the pests, tuber moth continues to be a major pest and yet there is no effective method for its control. Pre- and post-harvest treatments relevant to tuber health are also important in minimizing the extent of contamination of diseases during storage.

(e) Agronomic advances

Another important aspect of potato culture in the lowland tropics is to develop improved production technology under the conditions of small holdings to optimize resource inputs. In view of the worldwide shortage of energy, studies on efficient use of fertilizer must be emphasized.

In Brazil, farmers use up to 6 t/ha of fertilizer mixtures. Research conducted at latosoils of the Cerrado Region shows that economical applications are between 2 and 4 t/ha of a 4-14-8 mixture and varieties differed in their efficiency in nutrient uptake. In these tests, the local variety "Aracy" is a high yielder with lower fertilizer applications (Table 6). For these latosoils, the source of N, P, and K that carry along other nutrients such as Ca, S, and others have been showing a greater importance. High solubility may permit the loss of nutrients through leaching due to the heavy rainfall or improper irrigation schedule.

Nitrogen applications were most efficient at 120 Kg/ha. Also a less soluble nitrogen source such as ammonium sulfate was desirable.

Irrigation facilities are normally needed for potato to overcome water stresses during dry spells in the rainy season or to give proper water supply during the dry season. In the latosoils of mid elevation regions of Brazil, irrigation frequency of 4 days during the crop cycle, provided better yields with lower costs (Figure 2) than did other treatments.

Table 6. Influence of fertilizer applications (4-14-8) on yields of 3 cultivars in a new red latosoil of Brasilia D.F., 1981[1/]

Fertilizer t/ha	cv. ARACY	
	1980	1981
0	12.1 B	12.2 C
2	48.5 A	24.5 B
4	46.9 A	30.0 AB
6	50.1 A	29.9 AB
8	46.8 A	32.8 A
Tukey 5%	14.24	5.71

Fertilizer t/ha	cv. ACHAT	
	1980	1982
0	9.9 B	3.4 D
2	32.7 A	14.6 C
4	41.2 A	18.9 B
6	42.4 A	23.8 A
8	45.4 A	21.9 AB
Tukey 5%	16.96	3.66

Fertilizer t/ha	cv. BINTJE	
	1980	1982
0	11.7 C	4.8 B
2	25.8 B	9.6 B
4	31.4 AB	15.6 A
6	33.6 A	14.6 A
8	29.6 AB	14.6 A
Tukey 5%	7.21	4.79

[1/]After Lindbergue and Campos, 1982.

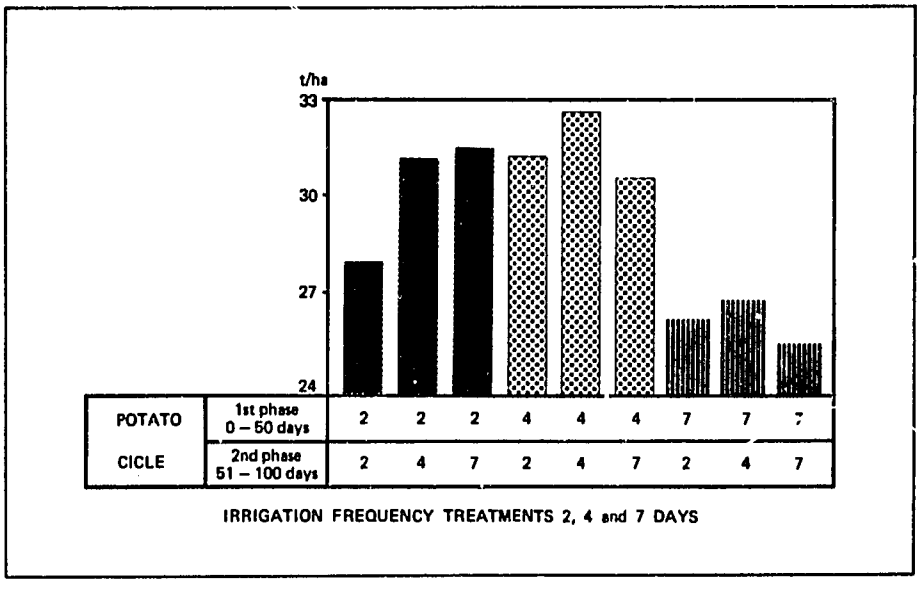

Figure 2. Effect of frequency of irrigation on potato production in a latosoil in the Cerrado Region of Brasilia-Brazil (After Carrijo and Silva 1981).

In lowland and humid tropical regions, agronomic techniques may be used to give better conditions of temperature and moisture to the potato. Research conducted by Midmore (1980) in Yurimaguas- Peru indicates that agronomic practices may modify the microclimate at the planting sites and permit an increase in production. Mulching with rice husks, maize stalks, or dry grass leaves, lowers the soil temperature during the day and avoids excessive evaporation from either ridge or flat planting. Additionally, it prevents erosion caused by heavy rainfall. Plant emergence was faster resulting in high plant stand. Yield increases of 30% were obtained. Soil reflectants may also be used with success. Chalk applied to soil surface after planting, increased yields by 80%, by modifying soil temperature. Plants produced better marketable tubers with higher dry matter and less tuber moth damage.

Planting in closer spacing up to 110,000 plants/ha gave an earlier crop cover over the soil, reducing soil temperature and increasing yields.

The multiple cropping system may also be very effective in the lowland tropics. The potato may receive and give benefits to a shadowing crop and the farmer may have income raised by double harvests. The taller crop may be a permanent one such as bananas, coconuts or a temporary one, maize or cassava. Both types reduce soil temperature by shading. However, the competition of a growing crop such as maize or cassava to the potato need research on specific planting times for both crops, their water relations, nutrient competition, and others. Potato is more heavily fertilized than cereals and other agronomic crops, thus the nutrient residues will produce an increase in soil fertility for the next crop.

Summary and Conclusions

The paper reviews prospects for extension of potato production to lowland tropics and its role as a supplementary food crop, especially when per capita availability of protein in the regions with high population pressure has been showing a downward trend. The ecological restraints as are generally understood, do not present serious barriers for adaptation of the potato in the lowland tropics. Major problems which have limited potato growth are mainly of a scientific and technical nature. Socio-economic factors have, of course an overriding influence.

The low per unit yield and low per capita consumption in these regions are mainly due to lack of adapted, day length -neutral varieties, and rapid degeneration of seed stocks, apart from problems of crop husbandry, and storage in the warm climate following harvest.

Suggestions are made to solve these problems for effective potato cultivation in the lowland tropics. Breeding of photo-insensitive and heat tolerant varieties with built-in resistance to insect-transmitted viruses (PLRV and PVY), bacterial wilt, and late blight are the first priorities for the projection of its rational improvement. Breeding techniques to achieve these objectives were discussed.

Growing potatoes from true seed seems to be on the threshold of adoption in the lowland tropics where holdings are small and the farmers have scarce resources. This technology also offers a good rural employment potential. Genetic engineering would go a long way in producing commercially acceptable families with high yield and better disease resistance.

Procedures for a commercially viable system of potato tuber true seed production technology have been outlined for regular supply of clean seed that the small farmers can afford.

Need for standardization of improved production technology under the conditions of small holdings to optimize resource inputs through concurrent attention to non-monetary inputs has been emphasized. Pre- and post-harvest treatments and appropriate storage methods consistent with ecological conditions relevant to tuber health during storage could probably be developed through applied research for minimizing storage losses and stabilizing the marketing structure.

The importance of the potato as a component of the improved cropping systems in the lowland tropics was stressed. Current studies in Bangladesh indicate that it is possible to grow one crop of early potatoes followed by a wheat crop by adopting photo-insensitive wheat varieties during the same time period when traditionally only one crop of potatoes or wheat could be raised.

The aforesaid technological advances could have far-reaching effects in harnessing the potato in the lowland tropics as a low cost supplementary food.

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BEYOND THE FARMER: POTATO CONSUMPTION IN THE TROPICS[1/]

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Potatoes come in all sizes, shapes and colors. People also come in all sizes, shapes and colors. When you put people and potatoes together, the possible combinations are amazingly diverse. Potatoes are truly one of the world's most versatile foods. But too often, those of us intimately involved in the technical aspects of improving potato production think of potatoes only in terms of the forms we ourselves are most accustomed to eating. If we know potatoes as a luxury food, something to be eaten only on special occasions, we marvel that other people can consume them on a daily basis. Conversely, those of us who eat "our daily potato" cannot imagine an existence without them. Lifelong habits prevent us from seeing the broader uses and potentials of the potato, and at the same time discourage changes in traditional consumption patterns.

First domesticated in the Andean highlands of South America, the potato has moved around the world during the past 400 years and adapted to a wide variety of environments and an equally diverse range of human tastes and preferences. Narrowing our view to only the tropical developing countries, we find that in some it plays a fairly homogeneous role as a common vegetable, while elsewhere, consumption ranges from one to over one hundred kilos per person per year. To some, the potato is the "bread of life," while to others it is a taboo item, to be eaten with caution. This paper addresses the great diversity in potato consumption patterns. I hope to clarify, as well as to raise, some important issues concerning the potato's current role in the food patterns of tropical developing countries and its potential role for the future. (Much of the information presented in this paper was collected between 1979 and 1981 during a series of case studies conducted in Peru, Guatemala, Rwanda, Philippines and Indonesia. This project was sponsored by the International Potato Center. Final case studies will be conducted in Bangladesh and Bhutan, and the final report will be presented in December 1982).

Why study consumption ?

But first, why should we concern ourselves with consumption when our goal is to improve production? In response to this question, I believe that the specific role the potato plays in a national diet and the factors which determine and regulate its consumption levels must be considered when planning and developing technologies to increase production. It has often been assumed that merely increasing production will cause increases in consumption. However, there is a growing realization that "programs aimed at increasing the production of food, even if they are successful, must be accompanied by efforts designed to affect the distribution of incomes and patterns of diet" (Berg, 1981). The potential for increasing consumption of a food item is largely determined by its current role in the diet, and the extent to which that role can be altered, expanded or diminished as changes occur in supply or cost. Hence, it is essential to view the potato not only in terms of production, storage and marketing, but also in terms of consumption behavior. We must look not only at the farmer, but beyond the farmer if we are to succeed in providing more food for people to eat.

Very little has been written about potato consumption in the tropics. The major objective of this paper is to reduce that gap by providing a broad overview of the tropical potato consumption situation. The topics covered are organized into three themes expressed as questions:

I. How much potato is currently consumed in the tropics and by whom?

II. How are potatoes consumed and what factors regulate potato preferences and consumption patterns?

III. What is the potential for greater potato utilization?

In the space and time allocated for this paper, it is not possible to answer completely each of these questions. It is hoped instead that these initial answers will stimulate others to probe deeper into the complexities governing, tropical potato consumption.

I. Calculating potato consumption

Food balance sheets

The most frequently used method of calculating potato consumption is the food balance sheet (FBS). Such sheets are constructed to show the total supply of food available in a country for a given year (or period of years) offset by the itemized utilization of those foodstuffs (Farnsworth 1961:181). The food balance equation lists domestic production, imports and exports, and net changes in year-end stocks as the "supply." From this quantities used for seed, non-food industrialization, animal feed and waste are substracted. The remainder is labeled as the amount of potatoes available for human consumption. This is then divided by the total estimated national population to obtain per capita availability of potatoes. The equation is usually carried further to show the calories and grams of protein provided by potatoes per capita per day. Unfortunately, "per capita availability" is often erroneously referred to as "per capita consumption." This is erroneous for two reasons.

First of all, the information fed into the equation is often unreliable. On the sup-

ply side, determining total production of potatoes is difficult. The fact that they are usually grown in more isolated areas, in highland and mountaneous regions, on small discontinuous plots, discourages accurate official measurements of production areas. Potatoes are often grown more than once a year yet counted only once. Potatoes act as intercrops, multicrops, relay crops, secondary crops, or dooryard garden crops. As such, they are overlooked in national tallies. In northern Luzon, Philippines, for example, yields were officially estimated at 6-8 tons per hectare. But when farmer yield surveys were carried out, it was found that the actual average is 28 tons (Potts, 1981).

On the utilization side, inputs are also suspect. In many cases, seed rates in the tropics are estimated using temperate zone rates. However, due to the widespread use of marble-sized seed in many countries, the tons calculated for seed are overestimated. Waste factors of 10, 15, or even 20% are applied indiscriminately without regard to local habits of peeling, cooking or peel utilization. Many populations consume large quantities of the peel, leaving little if any waste. Waste determination is further complicated when peels or rotten potatoes are fed to animals that are subsequently consumed. In highland Peru, small shriveled potatoes - "waste" according to North American or European standards - are consumed and prized for their "sweeter taste" (Werge, 1979).

Waste in market places can also be overestimated. Poor quality potatoes, classed as waste in developed country markets, are sold but at very low prices in the developing countries. Often "waste" potatoes are "donated" to local institutions such as orphanages, or are "collected" by local beggars. Partially rotten potatoes are many times cut and peeled and sold in plastic bags, often at higher prices per kilo than whole potatoes. Potato waste differs widely and standard figures cannot be applied across the tropics. Total national population can also be underestimated, or overestimated in developing countries.

In light of the dubious quality of the inputs, it seems doubtful that the result, per capita availability, can be worthwhile. As one colleague put it, "garbage in, garbage out." However, even if all the inputs are accurate, the result cannot be called "per capita consumption." To do so implys equal food distribution among all ethnic, religious, socioeconomic, age and sex groups. This does not happen. Additionally, FBS cannot account for seasonality nor regional differences in consumption among these groups. In sum, sole use of the FBS makes it difficult not only to adequately calculate current consumption levels, but also to predict or estimate the potential for change in consumption rates or to identify target groups within a country for specific consumption-related programs.

Nutrition surveys

Other sources for calculating potato consumption are nutrition surveys, which are conducted at national, regional and local levels. They are useful for determining potato consumption on a daily basis, and, depending on the quality of the survey, to distinguish patterns of consumption according to regional classifications, socioeconomic status, price fluctuations, or seasonal availability. Such surveys measure total consumption of a large sample of people for a period of time (24 hours, 3 days, or a week) to calculate daily intake averages and annual consumption rates for the area under study. Surveys conducted in rounds during a year can indicate seasonal consumption of certain items.

Though nutrition surveys supply a wealth of information on potato consumption, there are three problems which limit their usefulness. First, their goal is to measure caloric and protein levels in the subject population to determine dietary adequacy. Often foods are grouped together and their nutritional contribution is considered as a unit, for example: "root and tuber crops." Depending upon the level where the grouping took place, it may or may not be possible to separate potato consumption from that of other foods. Second, if a recall method is used, and the potato plays only a nominal role in total intake, the informant may simply forget any potatoes consumed. This is especially true if the recall period is longer than 24 hours. Finally, these methods cannot adequately measure potatoes consumed only on special or ritual occasions since nutrition surveys normally take place on working days and not on Sundays, holidays, Holy days or festival days. Food consumed only on these days could very well never appear in such consumption tallies. It is true that consumption of luxury or special foods may not have high nutritional significance, but estimating their periodic demand so as to plan for production, marketing and storage is quite important.

Both food balance sheets and nutrition surveys should be used as the starting point for calculating potato consumption. Despite their limitations, they can provide indications of availability and some consumption trends. In addition, since most international and national statistics are based on them it is advisable to take them into consideration. They are, in effect, the official position on the subject.

However, to make correct decisions on priority areas for potato promotion, more reliable estimates of consumption are needed, as well as an understanding of why people do or no not eat potatoes. Consumer responses to potato price, size, color, quality and origin and their inclinations towards altering their potato consumption must be determined. To do so requires talking to consumers.

Consumer surveys and consumer groups

There are numerous methods and manuals for conducting consumer surveys (Den Hartog and van Staveren, 1979; Christakis, 1978; Chavez and Huenemann, 1981). Time, budget and personnel constraints will usually set limits on the depth and extent of any survey, including ones on potato consumption. Speaking generally of all surveys, it has been shown in several situations, that most of the information, at least enough to make initial planning decisions, can be gathered with informal surveys (Rhoades, 1982, Ruano and Calderón, 1981).

Informal surveys replace lengthly, difficult questionnaires in favor of open, spontaneous dialogues and conversations with a variety of informants. The informal survey eliminates costly data processing and the normal timelag between survey and results and recommendations.

Whatever interview method is employed, the most useful procedure to follow is to disaggregate the consumers along the chain connecting production zones, markets, and urban and rural households. Interviews and observations at each link in the chain allows identification of homogeneous consumer groups, their average rate and frequency of consumption and the constraints or factors which regulate their consumption. This type of qualitative information also provides the means to estimate the potential of each group to increase or decrease potato consumption according to changes in cost or supply. Specific consumer groups vary from country to country but as a minimum, the national population should be disaggregated according to agroecological zones and urban or rural residence. This produces consumer groups sharing common consumption characteristics such as described below.

1. Potato producers. Farm size, land tenancy, and the number of potato crops planted per year will distinguish subgroups within this group. Consumption can vary a great deal among potato producers. Some will store large quantities to last all year until the following harvest. Others store only small quantities and produce several times a year, supplementing their stocks with supplies from the marketplace. Some do not store at all, consuming potatoes only at harvest time. Though some potato farmers are said to be strictly commercial producers, it is rare to find a producer who is not a consumer as well.

2. Non-potato farmers in potato production zones. This group has greater access to potatoes than rural non-producers living in non-production areas, since they can harvest potatoes and receive a portion of their payment in kind, exchange their production for potatoes, or purchase directly from neighbors at low prices.

3. Non-potato farmers outside potato production zones. These people theoretically have the least access to potatoes, must pay the highest potato prices and perhaps have the least familiarity with potato consumption, especially if they live at great distances from the influences of urban dietary habits. It is necessary to determine the relative importance of price and availability in limiting their consumption and whether there are other consumption constraints, such as ethnic background, food taboos or social status.

4. Potato marketing people. Other than potato producers, potato whole-salers, retailers and small vendors have the greatest and most regular access to potatoes at the lowest cost. It is felt that this group is the best indicator for the potential consumption of a non-producing population if constraints of price and availability are removed. Additionally, market people are often the best informants on buying habits and preferences of the larger study populations.

5. Urban residents in potato production zones. Potato prices and seasonal availability patterns can differ here from urban areas in non-producer zones. Market centers in production zones usually have lower prices than other cities especially at harvest times, and the residents have more familiarity with the use of the potato in the diet. It is important to separate this group from the other, because their consumption levels can also indicate

the overall potential urban consumption if prices are lowered.

6. Urban residents in non-potato production zones. It is necessary to consider separately those persons living in small urban settings from those in regional or national capitals, since the latter normally receives larger proportions of the potatoes marketed. Capital city populations can also receive greater potato consumption motivation from the influence of western expatriate residents.

In each of the above groups, stratification by socioeconomic status will reveal further differences in potato consumption and provide a rough estimate of the income elasticity for potato consumption. Generally, in the developing countries, excluding Andean South America, potato consumption is higher among wealthier than poorer people within the same consumer group. This should be viewed with caution, however, since it is not known whether this actually reflects genuine preference for more potatoes specifically, as income levels increase, or if it indicates general increases in all food-stuffs with higher incomes.

Special consumer groups

In every country there are special groups which, because of certain economic, social, cultural or political factors, demonstrate potato consumption patterns that differ greatly from the groups described above. Some examples of these are presented below.

1. Expatriates. Certain expatriates living in the tropical developing countries bring with them a set of food habits which are accomodated to the new environment, but nevertheless, not radically altered. Potato eaters removed from potato areas will still maintain high potato consumption levels even when potato prices are high. Often potato producers, merchants, and agricultural planners will claim (without justification) that expatriates are the biggest clients for potatoes. The extent of their influence on native food habits, especially in colonial situations and their continuing influence should be evaluated separately from other wealthy or elite groups.

2. Ethnic groups. Ethnic groups sharing the same agroecological zone, urban residence and socioeconomic classification can vary according to potato consumption. In Indonesia, the ethnic Chinese are found to have higher consumption levels than non-chinese city residents of the same socioeconomic level. The Minangkabau people of Indonesia consume large quantities of marble-size potatoes in preparations not common to the rest of Indonesia.

3. Pre-school children. Potatoes are used as a weaning food or a supplement to breast feeding in many countries such as Guatemala, Rwanda and the Philippines. In some cases, they are fed to young children exclusively while the rest of the family eats other foods. Often such consumption is excluded or overlooked in household surveys. The ages children are fed potatoes, preparations, taboos, and frequency of consumption should be determined to estimate potential utilization.

4. Hotels and restaurants. These can constitute the major bulk buyers of potatoes. They must meet special consumer preferences, such as those of tourists, which may differ from national consumer preferences. Care must be taken not to focus potato improvement plans only on the hotel and restaurant trade, but on local demands as well.

5. Nutritional and agricultural professionals. Taken separately, this group has the greatest access to accurate information about the use of the potato. Compared to equivalent groups their consumption habits reveals the effects of education and exposure on potato consumption.

Not every country will have all of the groups described in the preceeding paragraphs, nor will the variations between official per capita availability and consumer survey results always be of the same magnitude. Some examples of consumer survey results in countries with high or low reported per capita availability are presented below to demonstrate this variability.

Consumer survey results in selected countries

1. Indonesia. Food balance sheets constructed in 1978 for Indonesia, the fifth largest country in the world in terms of population (149 million), reported a per capita availability of 1.35 kg person/year (Indonesia 1978). A nation wide household survey (Indonesia 1980) reported average consumption rates that were lower (see Table 1) for the country as a whole but higher for urban areas than rural areas. Separating the household survey results for only one of Indonesia's islands, Java (60% of the national population), rural and urban consumption was reported to be lower than the country as a whole.

Table 1. Potato consumption: Indonesia (kg/person/year, 1978).

Food Balance Sheets	1.35	
National Household Survey	1.04	
Rural		1.04
Urban		2.08
Java Household Survey	1.04	
Rural		0.52
Urban		1.56

Because the national statistics are so low, it is widely believed that potatoes play an unimportant role in the national diet and economy. Yet within the vegetable research section of the Ministry of Agriculture over 40% of the research budget for 1981-1982 was allocated to potatoes. Better information on potato utilization was needed to determine whether this budget expenditure was justified.

In 1981, informal consumer surveys were carried out in West Java province to identify homogeneous consumer groups and to compare their rates of potato consumption with the reported statistics. Surveys were conducted in a highland vegetable and potato production zone, a lowland rice-growing zone and several urban centers including the national capital, Jakarta (see map, Figure 1). Some of the survey results are presented in Figure 2.

None of the consumer groups identified had a per capital consumption level equal to the estimated per capita availability. In both urban and rural areas, the wealthier residents had higher rates of consumption

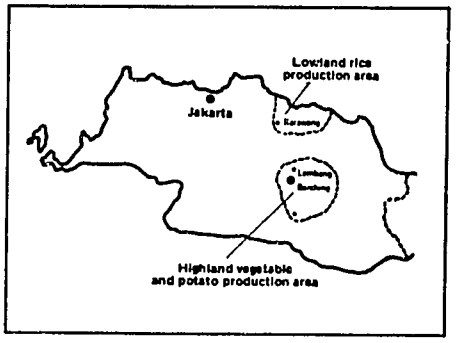

Figure 1. West Java: Potato consumption study sites.

than poorer people. Interestingly, poorer lowland rice farmers had similar consumption levels as poorer urban residents or production zones, indicating that lower prices and greater availability may not automatically encourage greater potato consumption. Expatriate interviews showed that indeed, their average consumption levels are higher than any other group, but even so, they are lower by half than the average consumption levels in their home countries.

Potato farmers have the highest consumption levels, yet again, wealthier farm families consume more than the poorer ones. In some cases this is due to the latter's lack of sufficient storage facilities, but for many the reason is because they sell the larger portion of the crop to provide family income. Wealthier farmers also sell the majority of their crop but they can afford to purchase potatoes when home supplies run out.

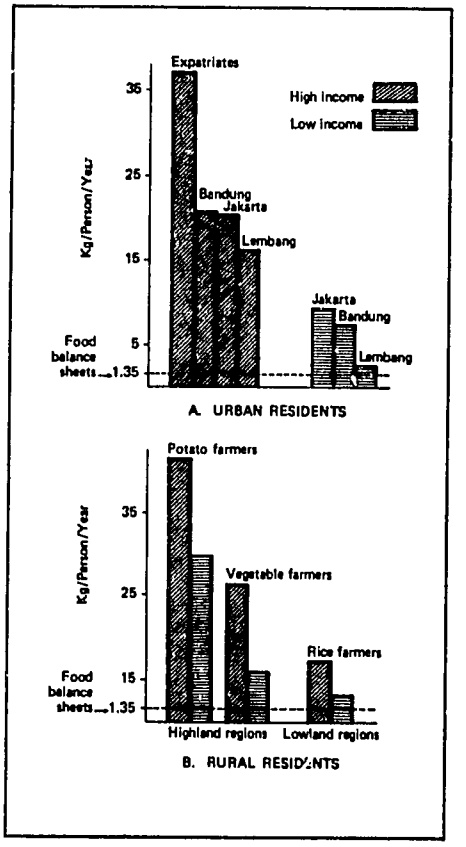

Figure 2. West Java: Disaggregated consumption levels.

This kind of information provides a better picture of the consumption situation and facilitates decision-making concerning potato research and extension such as where ware storage needs are greatest or who might benefit most from initiating potato cultivation. It also demonstrates that potato consumption is not restricted to the wealthy or to select urban areas, but is widespread throughout the province. It also supports the need to re-examine productions statistics, since with much higher levels of consumption, production must have been underreported.

2. Rwanda. Located in the Africa highlands at the watershed of the Nile and Zaire rivers, the tiny country of Rwanda (5 million inhabitants) reports the highest per capita potato availability of Africa, 46 kg/person/year (International Potato Center, 1982). Consumer surveys conducted in 1980 throughout the country show that in production zones, zones contiguous to production zones, and in urban centers, average consumption is a great deal higher than 46 kg while for other regions, consumption is quite low (Figure 3, Table 2). The average for two major urban centers was also high at 153 kg/person/year.

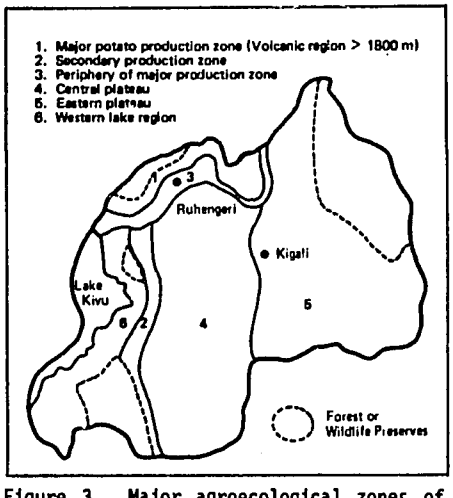

Figure 3. Major agroecological zones of Rwanda.

As with Indonesia, this information indicated higher production than currently reported, and corroborated field observations of higher than average yields as well as extensive use of potatoes as an intercrop with non-food cash crops such as pyrethreum. Though only roughly 10% of the national population lives in urban centers, this percentage is growing and more potatoes will be needed to supply the increasing demands. Potato program leaders previously thought that inhabitants in the Central and Eastern plateau regions did not consume potatoes, yet consumption, though comparatively low, does occur.

Table 2. Potato consumption in Rwanda.

Zone	kg/person/year
1	261
2	125
	72
	28
5	26
6	Not available

Informants in these areas reported a desire to consume more potatoes yet they had disappointing results in attempts to produce their own crops. Shifting some priority in the national potato program to the introduction of new production techniques in such areas would have considerable potential impact on increasing household consumption level.

3. Guatemala. Guatemala, with a population of 6,600,000 is the largest potato producer in Central America. Though potatoes have been produced in the Guatemalan highlands for centuries, per capita availability is reportedly quite low, only 4.5 kg/person/ year (Christiansen, 1980). Examination of nationwide nutrition surveys (INCAP/ ICNND 1971) indicate that consumption is probably much higher (Table 3).

Looking only at urban consumption in the capital, Guatemala City, (Table 4) consumer surveys carried out in 1981 provided much higher consumption levels among each of the three income groups examined than the two above-mentioned estimates. It is unlikely that potato consumption has vastly increased, but rather by focusing on potatoes exclusively in a survey provides more accurate consumption recall than when all elements of the diet must be recollected by the informant. There was little difference between middle and high income groups, but the low-income group was 10 kg lower. The majority of the informants in this category expressed a desire to consume more potatoes, but that the cost prohibited them from doing so. Among the upper income informants, few expressed a desire to consume more, stating that what they currently consumed was sufficient. This seems to indicate a potential among low-income groups to consume more if prices could be lowered, but that this potential has a ceiling or level of sufficiency at around 35 kg/year.

Table 3. Guatemala: Per capita potato consumption.

Location	kg/person/year
Urban (n = 100)	13.32
Rural (n = 206)	6.0
Total (n = 306)	8.32

Source: INCAP/ICNND, 1965-67

Table 4. Guatemala city: Urban potato consumption, 1981.

Income group	kg/person/year
High n = 10	36.9
Middle n = 21	35.8
Low n = 24	25.1
TOTAL n = 55	28.7

4. Peru. A final example is Peru. Per capita availability is estimated at 63 kg for 1981 (Scott, 1981). Despite the fact that Peru is well-known for its high levels of potato consumption, there is a great deal of variation within the population, which can be seen if the four major agroecological zones are examined (Figure 4).

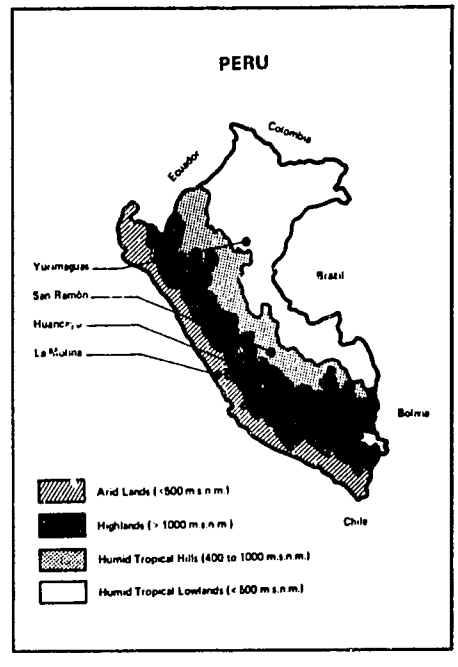

Figure 4. Agroecological zones of Peru.

In the Andean highlands, potatoes are a primary food source and are consumed on a daily basis often in quantities of 0.5 kg/person/day or more. Per capita annual consumption levels of 100-200 kilos are common and a wide range of traditional varieties are produced to meet home demands for different preparations and tastes.

In the eastern mid-elevation zone, Peru's 'ceja de la montaña', potatoes play a vegetable role in the diet, complementing other locally produced roots and tubers as well as a variety of fruits and vegetables. Though potatoes are normally not produced extensively in this zone, they are readily available in markets, or can be traded from neighboring highland zones. Consumption levels vary widely, from 10 to 100 kg/person/year, depending on the frequency of family access to a potato source.

In Peru's lowland humid zone, the Amazon basin region, potatoes are imported over great distances at high cost from highland production zones, or even from Lima wholesale markets. In part, their high cost makes them a luxury vegetable, available only to wealthy urban residents, but also relative unfamiliarity with the potato in addition to abundant availability of other local root crops causes potato consumption to be quite low, often as little as 1 kg/person/year.

In the larger cities of Peru's dry coastal zone, potatoes play a regular role in the diet due to their fairly constant market availability at comfortable prices. Potatoes are co-staples with other foods such as noodles, rice, sweet potatoes and

bread. Consumption levels average between 50 and 100 kg/person/year. For rural and small town coastal residents, potato consumption is often highly seasonal, occuring only immediately following the cool season harvest. During the hot season potatoes may either be unavailable or at prices too high to be affordable.

II. How and why potatoes are consumed

Patterns of consumption

The examples presented in the case study summaries of the preceeding section demonstrated who is consuming potatoes and in what quantities. The overall conclusion is that there is tremendous diversity in the manner in which people consume potatoes, and that it is difficult to generalize or summarize the diversity. But if attention is shifted from the "diversity" to the common features among all the potato consumers, they can be grouped according to "how" they are consumed. "How" does not refer specifically to the means of preparation, but to the quantity consumed at any one meal, the frequency of consumption and the relationship of potatoes to other food items comprising the meal.

Figure 5 depicts graphically the 4 positions potatoes can occupy in a meal. Each large circle represents the plate or bowl holding the principal or staple food item(s) for the meal. Smaller bowls represent major or minor side dishes that complement the staple food items. An "x" marks the place of potatoes in each hypothetical "meal."

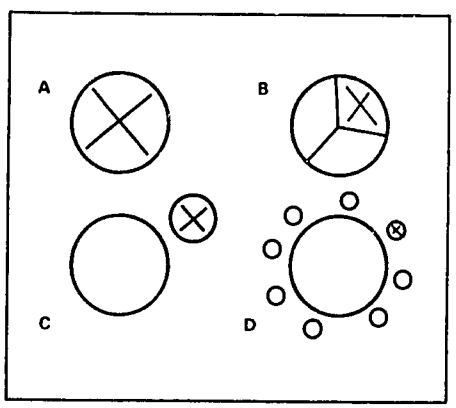

Figure 5. Possible positions of the potato in a meal.

Potatoes may occupy the entire place (Figure 5A) indicating their predominance as the main staple item in the diet. This pattern was common in Ireland prior to 1845 when an average of 3.5 and up to 7 kg of potatoes a day were consumed by the Irish peasants who had little else to eat (Woodham Smith, 1979). Today, highland peoples of Rwanda, Nepal, Tibet, China, Peru, Bolivia and Ecuador also exhibit the same pattern, adding a variety of spices and sauces to the ubiquitous plate of potatoes.

The potato can be in equal distribution (Figure 5B) with other staple foods, all of which can be alternately termed as co-staples. This pattern is common in European countries, the United States, as well as segments of developing country populations. An example of this pattern is often found in Peru's city markets where potatoes, rice, and wheat noodles may all be served on one plate in equal portions for a fixed price. For urban people in most of South America, potatoes join rice, noodles, cassava, sweet potato and plantains as the optimal counterpart staples consumed with meat, fish, poultry, eggs, or legumes.

The potato may serve as a major side dish to the principal staple(s) (Figure 5C). In this case potatoes complement the meal, but do not replace the staples. This pattern is seen in Central America where corn 'tortillas' and beans, form the mainstay of the diet, and potatoes are a 'vegetable' side dish, consumed on a regular basis, but in comparatively smaller quantities and not every day. The same pattern is reported for South Asia, in India or Bangladesh where potatoes are one of the major vegetable complements to the staples of rice, wheat and legumes.

Finally, Figure 5D represents the instances where potatoes are only one small item among many other dishes prepared to complement the basic staple element(s). This pattern is common to Indonesia, Malaysia, Philippines, China and other Asian and S.E. Asian countries. The actual quantity that any one person consumes may be quite small, but the frequency with which they appear in the meal may be quite high.

A typology of potato consumption

Observed patterns of consumption are used to construct a typology of potato consumption (Table 5) Patterns A and B from Figure 5 are combined in the first role, and patterns C and D comprise the second role. When potatoes are consumed in patterns C or D but in greatly reduced quantities and frequency, such as only on special occasions or as an infrequent luxury, then the third typology role applies. Finally, when no potatoes are consumed at all, the last role is applicable.

Cross-culturally, there are certain food beliefs concerning potatoes that are linked to each role. When potatoes are consumed as staples, they are usually valued for their energy-producing capabilities. Potatoes may be lumped with grains as well as other tubers, and thought of as "oversized grains" or in a category of their own, but never grouped with vegetables such as greens, cabbage lettuce, or radishes. The statement "a meal without potatoes is not a meal" is commonly heard in association with this role.

In contrast, potatoes considered as complementary vegetables or special foods are not judged as having "food or energy value." In many Asian countries, it is often found that "rice is food" and all other items, including potatoes, are merely "trimmings, garnishings, or flavorings to rice".

In the Philippines, it is often heard that, "if a man eats rice for breakfast, he can work all day, but if he eats potatoes, he is hungry by ten o'clock". In this role potatoes are lumped with vegetables. On the island of Luzon, Philippines, they are classed with other highland, cool-season, "high status" vegetables such as cabbage, cauliflower, carrots, cucumbers, and celery. In the Baguio city market, they can be found prewashed and plastic wrapped, as evidence of their high status. In the southern islands of the Philippines, potatoes are not so carefully displayed, and are often found among onions, garlic, ginger, and sometimes other root crops.

Associated with the vegetable role are certain beliefs about potatoes causing harm. In Guatemala the harm is part of the "hot-cold" food belief system in which a cold state is attributed to potatoes since they come from the ground. This does not refer to temperature per se but to intrinsic qualities of specific foods. Too much of a cold item or too frequent ingestion can cause harm or shock to a warm body. To be safe, they must be eaten in smaller quantities and combined or counter balanced with "hot" foods such as maize or beans.

Among some groups of people, potatoes are special foods, due either to high cost or certain social significance attached to them, which can also sometimes be related to the foreign cultures who first introduced potatoes. In the Philippines, potatoes are served at parties, special events like birthdays or weddings and at Christmas or Easter feasts. In Indonesia, potatoes are prepared in lavish dishes and exchanged to repay or cement social ties during Lebaran celebrations which follow Ramadan, the Moslem month of fasting.

In the final category, potatoes as a non-food, complete unfamiliarity with potatoes is fairly restricted to certain isolated groups and lowland areas where lack of availability or extreme cost prohibit their consumption among all except the very wealthy. There are individuals among potato consuming populations who, due to

Table 5. Typology of potato consumption.

Role	Frequency	Rate	Beliefs
Staple or co-staple food	5 + meals/week	± 60-200 kg/year	Potato = food or energy Meal is incomplete without potatoes
Complementary vegetable	1-7 meals/week	± 10-60 kg/year	Potato ≠ food or energy Potato = vegetable Potatoes are harmful if consumed frequently
Luxury or special food	1-12 meals/year	± 0.1-10 kg/year	Potato ≠ food or energy Potato = special food Potato = rich people's food
Non-food	Never consumed	0.0. kg/year	Potato = food for other people Potato is unknown.

medical, dietary or idiosyncratic reasons, do not eat them, but they are relatively few and far between. These persons usually do admit, however, that potatoes are 'food', but for others.

Consumption role and potato prices

The typology is useful in predicting how consumer groups will react to changes in potato prices. It is proposed that each of the first three consumption roles has a different response to price fluctuations. These are presented in Figure 6. Those persons who consider potatoes as a staple can often consume over 200 kilos a year when they are available and inexpensive. Consumption, irrespective of price, does not go below a certain level, proposed here at roughly 60 kilos. To people with this consumption pattern, potatoes are a basic necessity, so even when expensive, they are still consumed.

When potatoes are consumed as complementary vegetable, consumption is highly responsive to price fluctuations but maximum and minimum limits of 60 and 10 kilos are proposed. If potatoes are cheap and available, they will be consumed more frequently; if expensive, less frequently, but the intake at a given meal remains fairly stable. Consumers in this role with average annual intakes in the upper ranges (35-50 kg/year) will commonly state that they do not want or need to consume any more potatoes even if they become very cheap.

The most interesting pattern displayed is that of the luxury vegetable role. As stated earlier, when potatoes are considered as luxuries, they are consumed only at special times, usually holidays or religious celebrations. People buy large quantities of potatoes at these times to prepare special foods. Vendors know that potatoes are status symbols and must be obtained, so they increase their prices to their highest annual levels because they are confident that they will be able to sell all they have available. To meet this increased periodic demand, farmers practice delayed harvesting and merchants hoard potatoes in order to bring prices up. After these times, prices drop again but so does demand. This results in the "blip pattern" shown on the chart.

The diagram in Figure 6 shows that consumption roles are not created by price factors, but rather the roles respond to price situations with specific reactions congruent to the nature of each role.

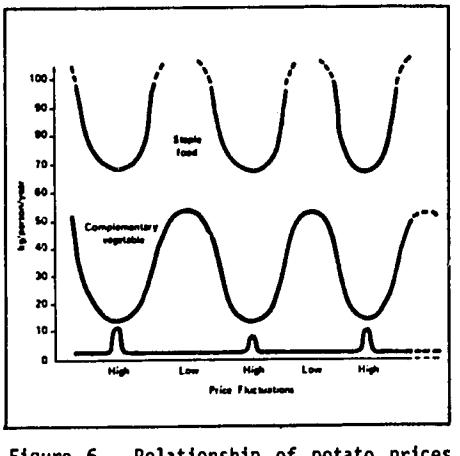

Figure 6. Relationship of potato prices and consumption role.

Throughout this paper, certain factors have been mentioned as influencing the role potatoes play with certain consumer groups. It is now useful to examine these and the other factors together.

Factors influencing potato consumption roles

Figure 7 shows factors which can influence the role of the potato in the diet, expressed here in the central box as the quantity and frequency of potato consumption. Price is placed closest to the central box because it is often the most obvious factor, the easiest to measure and one many times thought to be the most important. In fact, price is the last factor. Once the role is established, price modulates the consumption according to role patterns. It is the other factors arranged around the outer circle which in groups, act to formulate the specific role. Some of these such as rural vs. urban residence, income level, the type of agroecological setting, or whether one produces potatoes or not, have already been discussed. Some of the food beliefs associated with each role have also been described, as well as the effects of seasonality and availability on role formation. Some examples of how the other factors operate are presented below.

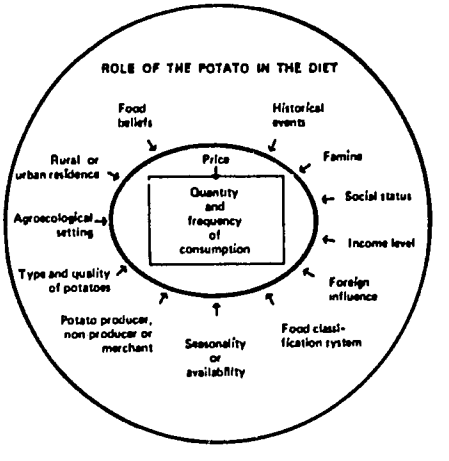

Figure 7. Factors influencing potato consumption.

1. Historial events. When introduced in Rwanda, potatoes were considered taboo items and not consumed at all. If a person ate them it was believed that their cows could become sick and die, or the milk could go bad. Tribal leaders, seeing that potatoes caused no harm among foreigners, especially missionaries, and had good production potential, forced local headmen to consume them and thus proved that no harm occured to people or cattle. Forced labor migrations of people from consuming communities promoted the spread of potato cultivation and consumption.

2. Famine. In both highland Rwanda as well as in Nepal's highlands, periodic famine in pre-potato times encouraged a rapid acceptance of potatoes once they were introduced. In these areas, little else could produce as well at higher altitudes. Since populations were hungry, potatoes were welcomed into the diet as a staple food.

3. Social status. Potatoes in Southeast Asia are expensive relative to staple foods or native vegetables, therefore, it is assumed that if you can eat them, you must be wealthy. Potatoes are also symbolic of western expatriates who normally enjoy high social status while residing abroad. Thus, conspicuous consumption of potatoes at special occasions is a way of demonstrating to others that a high social status level has been achieved. In Singapore the younger generation is reported to be changing from eating only rice to eating potatoes as well. Potato consumption is viewed as symbolic of modern ideas. For young people, "status is to walk down Orchard Road while eating from a package of McDonald's French Fries." (Reported by Ms. Hazel Ong. Commercial Officer, British High Commission, Singapore.)

4. Foreign influence. Potato-consuming colonizers of tropical countries have greatly influenced local consumption habits. Colonial administrators often introduced potatoes and their cultivation where it was heretofore unkown. In Rwanda, Belgian school masters and missionaries encouraged consumption among boarding school children. The Dutch left behind in Indonesia, varieties such as Eiggenheimer, which are still widely grown, as well as a preference for white-skinned, yellow-fleshed potatoes. The English influenced consumption in Kenya as well as throughout South Asia. Potato production and consumption grew in the Philippines only after the American occupation, even though the Spanish had introduced potatoes over a century earlier. Today the McDonald's signs on the skylines of Hong Kong and Singapore are a new symbol of foreign influence on potato consumption habits.

5. Type and quality of potatoes. The types and qualities of potatoes can influence the consumption role, but also, the role responds to variations in type or quality according to a range of acceptable types, rejecting those that fall outside this range. Among Filipinos, marked preferences exist for red-skinned or white-skinned potatoes depending on the part of the country. In Luzon, red-skinned ones are used for cold salads while white-skinned ones are for cooking with meat or vegetables. In Mindanao, white-skinned potatoes are eaten, and red ones are often avoided because they are said to spoil quickly. In Indonesia, red or purple-skinned potatoes are produced in a few isolated areas, but they have little market value because consumers think they look like sweet potatoes, a low-status food, and they will not buy them. For years in Guatemala, a leading potato producing area was Santa Rosa. Potatoes from this area were preferred to as 'Papa Santa Rosa' and were highly esteemed by urban consumers. Today Santa Rosa no longer produces many potatoes, but merchants, desiring better prices for their potatoes, hawk them as Santa Rosa potatoes no matter what their variety or production location, and consumers pay higher prices for them.

The degree of importance attached to tuber size, shape, skin or cooking quality or color depends highly on the specific consumption role and the consumer group which displays it. For some, small potatoes are prefereable to large. Others desire a potato that holds a cube-shape when cooked, while some seek out potatoes that fall apart when cooked. Skin quality may be important to the staple consumers who eat the entire potato, but to vegetable consumers who peel and cut up potatoes to mix with other foods, the skin quality is of less importance. Above all, in each

group, no matter where or what role, consumers search for potatoes that taste good, then they identify these potatoes with names, origins, sizes, shapes or distinctive colors. Any new potato must not only produce well, but fit within the local ranges of acceptable taste.

III. Potato consumption in the future

Potential for changes in the consumption roles

Reviewing the consumption typology, the factors influencing consumption, and the price/role relationship, it is proposed that there is greater potential for luxury potato consumers to become complementary vegetable consumers, than for the latter to incorporate the potato as a staple food. As a luxury vegetable, the potato has a high status position in the diet. People would likely include it in ordinary meals, as a vegetable, if it were more readily available or cheaper. There is little difference between these two groups in terms of beliefs.

It is much more difficult to change potatoes from a complementary vegetable position to that of staple. Strong belief systems hold the potato to one or the other position. Usually in the vegetable role, other foods such as grains, legumes, or other tubers are considered staples and are more readily available. This does not mean that the change cannot occur (and it does), but that rather when it happens, the potato comes to fill a staple food role that was either previously unoccupied or poorly occupied by local foodstuffs.

Our goal for the future should be to facilitate greater frequency of consumption among those who regard potatoes as vegetables, by working to:

- reduce the price of potatoes relative to other vegetables;
- encourage wider market distribution on a more regular basis;
- improve home potato storage;
- promote varieties suitable to local vegetable preparations;
- provide information on new methods to incorporate potatoes into local diets.

In line with the last of these recommendations, processing and weaning food preparations are two vehicles suitable for encouraging greater potato utilization. Both merit further examination here.

Potato processing

Techniques for processing potatoes were developed in the Andean highlands over 1000 years ago, yet processing has only become widespread in the developed countries since World War II. In fact, potatoes led the "food revolution" which brought the processing industry to its present level of importance.

Processed potatoes are rapidly supplanting fresh potatoes, and in the U.S. alone account for over half the annual consumption. Yet in the developing countries, potato processing accounts for only a tiny fraction of the consumption. (FAO reports that only 0.1% of the potatoes produced in developing countries are manufactured for food. However, their term "manufactured" is much more restricted than "processed" which can apply to frozen and fried potatoes. Additionally, since FAO does not even report Peru and Bolivia's potato processing, where the techniques themselves were invented, it is likely that the statistics are as a whole, far underestimated.)

If the trends for consuming processed potatoes among higher income groups in the developing countries are similar to those in developed countries, then we can assume that the demand for such items will increase in the future. However, we should not limit ourselves to the narrow prospects for promoting potato products among the relatively small groups of wealthier developing country inhabitants. Potato processing has a much broader applicability.

Processing can provide an alternative or an extension to storing fresh potatoes. Transforming them into flour, starch, dried or freeze-dried products makes them easier to store for long periods, less expensive to transport, concentrates the nutritional quality by eliminating the water, and often increases their unit value. Processing also offers a means to utilize poor quality potatoes, and bring a higher price for them than if sold as animal feed, which often happens. Processing can also improve the nutritional quality through the addition of nutrients, such as mineral (iodized salt) or by increasing the caloric density by adding oils during frying.

When considering processing, we should not be bound to images of elaborate factories and machinery. Such items may indeed have a role in the developing countries, however a much more pressing need is for intermediate or rustic processing, something that can be conducted inexpensively, with small capital investment, at the village or commune level, with relatively inexperienced operators and managers, and operated with relatively small quantities of potatoes at a time. Such techniques and rustic processing devices have been developed in Peru and Bolivia, but exploration remains to be done as to the applicability of these to other contexts and situations. In Peru, 'chuño' native freeze-dried potatoes, and 'papa seca', dried potatoes, form a significant part of the highland diet. We should investigate whether these same products might have a place in the diets of non-Andean populations.

We must be inventive and innovative in the search to develop the potentials of potato processing. We must look for the places in local dietary patterns where a processed food might fit in. Not all items are easily, nor justifiably, transferable. In Guatemala, for example, processed potatoes fit well into several dietary niches. French fried potatoes are rapidly becoming the preferred complement to local fried chicken, 'pollo campero.' Potato chips are sold in urban areas on street corners, and at movie theaters, and as a part of the general 'street food' consumed by the urban workforce. One of the more promising processing avenues currently being developed locally is the fabrication of instant mashed potatoes. 'Puré de papa' or home made mashed potatoes, is already one of the most popular urban potato preparations, and thus the new, easier preparation, if moderately priced, has a good chance to become a success. Promotion of other items, such as potato flour to supplement wheat or corn flour, could meet with greater resistance, since it is not a customary practice and would alter the nature of the traditional staple food items.

In Indonesia it is difficult to find any examples at all of processed potatoes. However, many other food items, such as cassava, rice, nuts and plantains are processed into a variety of crunchy 'krupuk' a kind of giant spicy crisp, eaten with meals. Many other kinds of fried snack foods are sold and consumed among all socioeconomic groups. Occasionally, potatoes are also processed, into chips. It is possible that potatoes could play a more significant role in the 'krupuk' industry, however, at present, there are very few potatoes available for processing, since virtually all of the fresh commodity can be sold profitably at the local markets. It is also possible that the market is already saturated with processed food items and there is no need for processed potatoes.

In sum, processing holds much potential for diversifying potato consumption in the future. Caution must be exercized in application of processing technologies in that: (1) there should first be a place for the resulting product in the diet or plans formulated to develop that place, and (2) that the technology is appropriate to the overall farming and post-harvest system.

Potatoes as weaning foods

One of the reasons behind the extent of malnutrition in developing countries is the lack of good quality weaning foods for feeding the child when it has to be taken off breast milk (Mudambi and Rajagopal, 1980). Potatoes, either in a fresh state or after processing, mixed with other foods or made denser calorically through the addition of oils, provide an excellent weaning food for infants. Among many producer and merchant mothers in Central America and S.E. Asia potatoes are already used as a weaning food. However, among other producers, particularly those for whom potatoes are a relatively new crop, potatoes play only a very small role in the weanling diet.

Among many Filipino producer families, potatoes are only rarely given to children. Instead, costly items are purchased for baby food, rice, and sweet potatoes are imported from the lowlands, and potatoes are overlooked. Due to their bland flavor, low fiber content, facility of preparation, protein quality and balanced ratio of protein to carbohydrate energy, potatoes should be encouraged as an infant weaning food.

For the future, efforts should be focused among newcomers to potato production to encourage greater utilization of their product in their own diets and particularly those of their children. This will require innovative educational procedures and village-level pilot projects since food habits are the cultural traits most resistant to change. Yet, if potatoes are to be more widely consumed among these regions of the tropics, then the efforts must begin with children, and particularly children of producers and marketing people for whom price and availability are not constraints to increasing consumption.

Potatoes in a vegetable production world

It must be emphasized strongly that for a large part of the tropical world, the potato is considered as a vegetable. This classification places potatoes in a category often considered much less important

than cereal foods or other roots and tubers consumed as staples. Within such a system, it is difficult for governments to justify specific programs dealing only with potatoes, and even more difficult to allocate personnel to work solely on potatoes. Instead, potato research and extension must be combined with that of other vegetable crops such as tomatoes and cabbages. Potato development interests must orient their thinking particularly in Southeast Asia, towards promoting potato improvement within a vegetable farming system. We must not only be concerned with improving potatoes themselves. but with improving potato production within the highly intensive vegetable cropping systems common to a large part of the tropical world.

Conclusion

The ultimate goal of improving potato production in the tropics is to facilitate greater and wider incorporation of potatoes into existing dietary patterns. However, we cannot afford to look at potatoes alone. They must be viewed as a part of the larger food network, an addition, an increment, a complement, but not a substitute for other equally beneficial foods. Narrow thinking regarding the potato or viewing it as an exclusive monocrop or "mono-food" will not encourage its viability in the long run. Single-mindedness can cause disaster just as single-minded dependence on potatoes reduced the Irish population by half in the 19th century.

Even so, we spend a lot of time and energy calculating the benefits of one food over the detriments of another. We find better and more exact ways of measuring proteins and calories, and we try to figure out know many people can be suoported by the per hectare production of our favorite crop, or how many kilos it takes per day to nourish a person. The Irish are reported to have consum from 3.5 up to 7 kilos of potatoes per day to meet their food needs prior to the Great Famine (Salaman, 1949, Woodham-Smith, 1962). Many Andean people easily eat over 1.5 kilos per day. One calculation tells us that an average man needs 18 medium-sized potatoes per day to meet bodily needs (McCay and McCay, 1967). An experiment many years ago showed that male and female human adults could exist for 167 days and maintain nitrogen equilibrium and good health on a diet solely of potatoes (Kon and Klein, 1927). Potatoes alone are reported to provide and adequate protein source for human adults (Tudge, 1977). According to recent nutritional requirements standards (World Health Organization, 1973), an active 30 years old female can be maintained on 2.799 kg of potatoes per day.

We also compare the ability of potatoes to supply human needs versus bread, rice, sweet potatoes, corn, or cassava. But in reality, few people eat these items alone. A handful of beans, a bunch of greens, or some spoonfuls of oil, added to each erases the nutritional advantages of any single item over the others.

We must broaden our thinking about potatoes. Diversity is the goal of the human search for food. Diversity provides balance in the diet, and the correct proportions for enabling physical growth and body maintenance. No one food, no matter how wonderful, can truly meet all of human-kind's physical and social needs for food.

In the final evaluation, the success of our efforts in potato development will be measured not by total increases in production but by the quantities and frequencies in which potatoes appear in the cooking pots of the world. The evaluators of our products are the people who prepare them for our families' consumption. We should want to see potatoes added to the pot's total, but not replacing items already inside. When we regularily find a bit of potato in the daily bowl of food where it never was before, then we shall know our goals have been achieved.

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PROSPECTS FOR THE USE OF TRUE SEED TO GROW POTATO

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It is well known that the use of true potato seed (TPS) instead of seed tubers for direct production of ware potatoes has been a major objective of research at CIP and other institutes in the developing countries. Recent work of CIP indicates another important use of TPS, namely seed tuber production from TPS. This has been developed on a large scale during recent years in China. In addition, some experiments on true seeds sown directly in the field have been carried out at southern and northern regions of China.

The total cost of production for the supply of disease-free seed tubers through clonal propagation, and the substantial amount of money and expertise needed to produce it cannot easily be afforded by developing countries. Therefore, an alternate technology is made available through the use of TPS for raising potato crops, because most potato viruses, except PSTV, APLV, are not transmitted by true seed.

Experiments using either direct field sowing or transplanting seedlings from the nursery to the field, demonstrate that transplanting is superior. Most agronomic research of TPS seedling production has been conducted under both sub-tropic and northern environmental conditions in China. In comparison with transplanting seedlings, the young seedling derived from direct field sowing of TPS does not have enough reserve energy to maintain active growth in case of drought or insect attack. This is due to inherent defects, such as slow growing at the early stage and the long growing period required. In developing countries, where transplantation of seedlings from nursery to field is practiced and known to small farmers, and where human labor is not a limiting factor, the farmers would be able to raise a successful potato crop providing that suitable TPS be made available to them.

The southwest mountainous region of China has a long growing season covering about 200 days, and young seedlings need not be started under cover. Furthermore, rain-

fall is plentiful, about 1,000-1,500 mm during the potato growing season, thus seedlings can be transplanted from seedbed to the field successfully without irrigation.

Techniques for use of TPS to produce potato seed tubers have been successfully practiced in Inner Mongolia, Yunnan, Sichuan, Heilongjiang and Anhwei provinces. During 1967-1979, open-pollinated and intercultivar hybrid TPS were mainly used for raising seed potatoes. The yield of marketable potatoes derived from these seedling tuber seeds were 35-55% higher than controls. In order to improve this technique, commencing from 1978, the diploid hybrid (W5295.7) was used as staminate parent to cross with Tuberosum inbred lines (S_6 - S_7) and Andigena (Neo-Tuberosum) inbred lines (S_4), and Andigena to cross with Tuberosum, aiming at developing more vigorous and phenotypically uniform hybrids.

A trial was made to compare the yield potential of different F_1 hybrid seedlings, open-pollinated seedlings, and tuber families from hybrid seedlings and OP seedlings. Progenies of each of the family types were grown at Harbin (Heilongjiang province), Xichang (Sichuan province) and Jieshou (Anhwei province) during 1980-1981. The results suggested that yield of 4x-2x F_1 seedlings and F_1 tuber propagation were superior to those of intercultivars F_1 and OP seedlings. The mean yield of the group of 4x-2x crosses was the highest between hybrid groups and was significant, in the spring and autumn double cropping region (Table 1). The fact that progenies of 4x-2x hybrids have both large vine and tuber yield has made this excellent material for evaluating potato vines as a green manure. The progenies were relatively uniform and possessed short dormancy. They were adapted to the spring and autumn double cropping region where the spring crops were harvested at the end of June. The progenies can be replanted in mid-August following a short dormant period without GA pre-

Table 1. Average tuber yield and uniformity of seedling populations between different crosses (1980).

Parentage of seedlings	Families No.	Harbin		Jieshou	
		Yield 1/	CV 2/	Yield 1/	CV 2/
tbr($S_6$0 x Neo-tbr(S_4)	5	51.3	38.1	30.2	41.8
Neo-tbr(S_4) x W5295.7	4	45.1	40.2	32.1	41.2
tbr(S_6) x W5295.7	7	40.7	36.5	48.1	37.2
Cultivars x W5295.7	5	38.4	45.7	41.3	43.7
Epoka (OP)		39.6	46.0		
Epoka control		47.2	31.8		
White Bumper (control)				44.4	29.7

1/ Yield in kg of plot containing 100 seedlings.

2/ CV = coefficient of variation.

treatment. However, many of the 4x-2x hybrids resembled the 2x parents in appearance. They had deep eyes and a tuber type which was considerably less attractive than that of the 4x parents. A broader use of this breeding method must await development of more adapted diploid parents.

Mean yield of the group of tbr x Neo-tbr crosses was the highest between hybrid groups in Xichang, Sichuan province (Table 2). The progenies of tbr x Neo-tbr hybrid were more resistant to late blight that were others. Extensive segregation of resistance to wart found in families of these crosses was a disadvantage. Of 15 families, 3 family populations were resistant to wart with ratios resistant to susceptible 80.03 to 19.97 on the average.

Table 2. Average tuber yield and uniformity of tbr x Neo-tbr hybrid seedling populations (1980).

Combination	No. of families	Harbin		Xichang	
		Yield 1/	CV 2/	Yield 1/	CV 2/
tbr(S_6) x Neo-tbr(S_4)	15	49.4	40	53.3	40.4
3/		60.2	37.7	67.1	36.8
Intercultivars	5	39.2	57.2	44.1	55.3
Kunnae (OP)		31.2	48.1	41.3	44.2
Kunnae (control)		44.6	36.4	47.5	31.9

1/ Yield in kg of plot containing 100 seedlings.

2/ CV = coefficient of variation.

3/ S4-3-5-9-25-1-(21) x NS12-156-1 - the best one of the 5 shown above.

This susceptibility to wart can be traced back to both the original Andigena and Tuberosum clones. Therefore, it becomes imperative that selection for resistance to wart precede the breeding use of Andigena, because wart had been widespread in southwest mountainous region since 1979. However, 3 families, including two 4x-2x and one tbr x Neo-tbr hybrids, have been identified as uniform and high yielding, and will be used to raise the potato crop in the spring autumn double cropping region and Sichuan province separately.

The seedling transplantation method has been successful in raising commercial potato and seed tubers from hybrid seed in China and will become a routine method for potato cultivation in the southwest mountainous region. It seems evident that the technology of raising a commercial potato and seed potato from true hybrid seed should hold promise for the developing countries. Looking ahead, we are filled with confidence. This would be especially true when both parents with good combining ability are complementary to disease resistance in such a way that the hybrid population, or the greater part of it, possess the resistance of both parents. It is believed that revolutionary changes are forthcoming both in technique for the use of TPS and potato agriculture, along with the development of potato breeding programs.

With regard to further research required for widespread application of this technology by the year 2000, the following proposals are recommended:

The inherent defects of TPS, such as slow growing at the early stage and the long growing period required are essential disadvantages in the use of TPS to grow potatoes. We need so search for a mutant with short growing period, adapted to direct field sowing, similar to the "topiary gene" which conditions early tuberization and very short stolons and a genotype setting greater numbers of tubers than is found in wild diploid potato.

PSTV is widespread in China. Because of pollen and seed transmission of PSTV, particular attention should be given to develop a technique for eradication of PSTV from parents used for true seed production.

It is necessary to develop a broadly based population of S. tuberosum ssp. andigena and clones of the group of diploid species S. phureja and S. stenotomum with good yield, agronomic characteristics, wide adaptation, and disease-pest resistance.

It is important to develop breeding methods for maximum uniformity and heterozygosity of TPS. The potential for true seed production justifies intensive searches for mutants which modify meiosis so that homogeneous gametes are produced.

POTATO PRODUCTION FROM TRUE SEED - PRESENT AND FUTURE

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Introduction

Potatoes can be propagated vegetatively from seed tubers or sexually from true seed. Traditionally, commercial production of potatoes has been based on the use of seed tubers for planting, while the use of true seed was limited to breeding and selection.

Potato production from seed tubers has been popular because of the ease by which tubers can be planted, the fast and vigorous growth of the plant, the uniformity of harvested tubers and its high yield potential. In spite of these advantages, the method has presented important problems which hampered the adoption and expansion of potato production, especially in developing countries. Among the problems associated with potato production from seed tubers are the following:

In developing countries, seed tubers are usually imported at high cost from European, North American, and Australian sources. It has been estimated that the cost of the two tons of seed tubers necessary to plant a hectare of potatoes can be from 30 to 70% of production inputs.

Seed tubers are often the source of disease and pest introductions.

It is not always possible to import seed tubers for certain planting seasons because of their unavailability from exporting countries.

In many cases, seed tubers often arrive late for a recommended date of planting and sometimes of poor physiological quality, often succumbing to rotting by microorganisms.

Imported seed tubers are of cultivars bred for temperate climates, and thus are often poorly adapted to growing conditions in importing countries.

Costly and often unavailable storage facilities are sometimes necessary before the distribution of imported seed tubers to farmers.

Seed tubers are bulky and perishable and, therefore, difficult to transport to distant or nearby but inaccessible areas of production in developing countries.

To overcome some of the above problems, farmers in some countries use seed tubers either produced locally by governmental agencies or by themselves. Locally produced seed tubers, especially in tropical areas, are generally of lower quality than imported ones in regard to tuber health and physiological quality, factors which contribute to low yields often experienced in developing countries. This situation is changing, however, as many countries are developing better seed tuber multiplication programs and storage facilities at high cost.

Because of the above problems associated with seed tubers, the use of true seed as a substitute for the traditional method has gained momentum in recent years. In China, the use of true seed has been successfully practiced in many communes and state farms in Inner Mongolia, Ninghsia, Yunnan, Kweichow, Szechnan, Heilunkiang, Honan, and Anhwei provinces. By 1979, seed tubers derived from true seed were planted on 21,660 hectares in China with an average yield of 29-155% more than standard cultivars (Li and Shen, 1979).

Research on true potato seed in recent years at the International Potato Center in Lima, Peru as well as in New Zealand, India, Korea and by few seed producing companies in the USA has shown the potentiality of using true seed as planting material, especially in developing countries.

The recent interest in using true seed as planting material stems from the following advantages that it has over seed tubers.

The cost of true seed is expected to be cheaper than seed tubers.

Transport of true seed from the production site to the farmer, even in inaccesible areas, is inexpensive, simple and does not require storage facilities during transit. One hundred gram of true seed can replace 2 tons of seed tubers required to plant one hectare of land and thus diverting it for use as food.

True seed may introduce potato cultivation into new areas where good quality seed tubers are difficult to produce or store economically.

True seed is easy to store for long periods of time in contrast to the expensive and specialized storage requirements for seed tubers. This gives the grower access to potato seed for planting at any time depending on climatic conditions and cropping systems.

Disease transmission by true seed is less than by seed tubers. To date, only two viruses (Andean potato latent virus and potato virus T) and one viroid (potato spindle tuber viroid) are known to be transmitted by true seed.

The use of true seed instead of seed tubers for planting has some disadvantages, although most of them are surmountable with further research. These drawbacks include:

Tubers obtained through the use of presently available seed progenies have less uniformity in shape, color, size and cooking quality than those obtained from cultivars grown from seed tubers. These deficiencies can be overcome by future breeding and selection.

Potato production from true seed requires more farming operations and labor inputs than from seed tubers.

Existing true seed materials usually produce lower yields and smaller tubers than from similar clones.

Seedlings produced from true seed appear to be more vulnerable to insect, pathogen and environmental stresses than young plants grown from tubers.

The above disadvantages are stated on the basis of our present knowledge of potato production from true seed and seed tubers. Most, if not all, of these disadvantages can be overcome as more knowledge and experience with true seed are gained and as superior progenies are bred.

PRODUCTION METHODS

Potato production from true seed has been approached in three ways:

1. Direct field seed sowing.
2. Transplanting from nursery bed to the field.
3. Planting of tubers derived from true seed.

Direct field sowing

Potato seeds germinate best at 15-20°C and are inhibited at temperatures above 25°C or below 10°C (Stier and Cordner, 1937; Steinbauer, 1957; Sadik, 1979). Even at optimum temperatures, they germinate slowly over a period of several weeks. Because of the low temperature requirement for seed germination, the applicability of this method according to our present experience is doubtful in hot areas where rainfall is torrential and poorly distributed and where soil crusting, weed, and pests are problems during early seedling establishment.

Kunkel (1979) failed to obtain seed germination in a well irrigated six hectare field by direct sowing seed that had 87% germination in the laboratory. The most likely factor that prevented seed germination was the high summer temperatures experienced after sowing.

Bedi (1978) and Bedi and Smale (1978), Bedi, Smale, and Burrows (1979) grew potatoes under sprinkler irrigation by direct seed sowing and transplanting in New Zealand. Crop performance varied from year to year depending on the environmental conditions during growth. In 1978, only about 6% of the total number of directly sown seed survived until final harvest, while in 1979, better total yield was obtained by direct seeding than by transplanting.

Accatino (1979) working with direct field sowing in several environments and with soils of different composition in Peru, concluded that the success of direct sowing is highly dependent on the edaphic and environmental conditions during germination and seedling establishment. In San Ramon when soil temperature was high, seed germination was poor and direct seed sowing was a failure, while during the Lima winter months (mean maximum temperature between 12° and 16°C), germination and seedling emergence and establishment from directly sown seed were satisfactory and resulted in good yield.

Production by transplanting

In this method, seed is sown in trays or ground beds containing soil of proper physical structure, fertility, and moisture as practiced for seedling production of other vegetable crops. If necessary, shading of the seed bed is provided to reduce the inhibitory effect of high temperature on seed germination and other stresses during seedling growth. Under such protective conditions, germination and seedling emergence can occur within one week and vigorous seedlings can be ready for transplanting within 4 to 5 weeks from sowing (Accatino and Malagamba, 1982).

This system avoids a number of problems associated with direct sowing in the field because seedlings are established under careful management in small protected areas where pests, edaphic and environmental stresses can be more easily controlled. Therefore, the system has promising applications, especially in areas where vegetable production by transplanting is a common practice.

Production from tubers derived from true seed

In this method, seedlings are grown densely in ground beds until tuber maturity. Seedlings are established either by direct seeding or by transplanting from nurseries. At maturity, tubers are harvested and stored until planting for production of potatoes for consumption or for seed tubers. From an open-pollinated seed progeny (DTO-33), up to 1000 tubers/m^2 of various sizes have been obtained (International Potato Center, 1981).

This methods combines the attributes of potato production from true seed with those of seed tubers. The advantages of this system include:

A grower or a national agency can produce seed tubers intensively in small protected areas where adverse conditions can be better controlled.

A grower has an opportunity to eliminate abnormal looking plants and off-type tubers. This in a way constitutes a further screening procedure to achieve tuber uniformity.

A grower that is accustomed to planting potatoes from seed tubers can adopt this system easily.

The early vigor of plants derived from seed tubers helps growers avoid problems associated with seedling survival and establishment from transplants.

A grower can usually expect better yields from plants grown from seed tubers than from transplants.

The system suffers from some disadvantages which include:

Seedlings grown in nursery beds can be infected with pathogens if proper insect control and plant handling are not practiced. These pathogens are in turn transmitted to tubers and result in plant infection in the field.

Plants produced from true seed generally produce a large number of small tubers some of which are not useable for field planting. These small tubers may have a tendency to lose more weight during storage, especially under dry conditions.

The method demands intensive labor and skilled management.

The method requires facilities for tuber storage until planting. However, such facilities can be small since tubers are small. Because seed tubers can be produced off-season, growers can program their planting and harvest in a way to avoid prolonged storage. It is anticipated that when an effective technique is found for breaking tuber dormancy before planting, the need for tuber storage may be eliminated.

PRESENT STATE OF KNOWLEDGE

Flowering

The physiological mechanism of flowering of potatoes is little understood and, therefore, simple and reliable methods to induce it are not available. Flowering occurs in various degrees depending on species, cultivar and environmental conditions. In general, Solanum tuberosum ssp. andigena flowers regardless of day length although better under short days; while S. tuberosum ssp. tuberosum usually does not flower under short days.

Certain cultivars of either species rarely flower under any condition or flower sparsely and for short durations. In general, flowering of S. t. ssp. tuberosum is enhanced by growing plants at about 20°C and 18 to 19 hours photoperiods (Patterson, 1953). Zafar (1955) working with two tuberosum cultivars, namely Canoga and Russet Burbank significantly improved flowering and fruiting by spraying plants with 25 ppm solutions of any one of seven hormones, especially 2, 4-D in the case of Canoga, and naphthalene acetic acid in the case of Russet Burbank. Frequent sprays with gibberellic acid significantly improved flowering (Fischnick and Krug, 1959; Pushkarnath and Chauchan, 1964). Other methods for promoting flowering and fruiting have been used. East (1908), Werner (1934) and Abdel-Wahab and Miller (1963) found that flowering was not promoted by stolon removal. On the other hand, Thijn (1954) and Jessup (1958) improved flowering in some cultivars by stolon pruning. Abdel-Wahab and Miller (1963) stimulated flowering in some varieties by wire girdling or stem incision, but, these treatments had no significant effect on sparsely blooming varieties.

The nutritional status of the plant and its effect on flowering has been implicated by Bolle-Jones (1954). He found that flowering of the cultivar Majestic can be markedly affected by the iron-potassium nutrition of the plant. Increased iron supply occasionally increased flowering at lower potassium levels but always decreased it at higher levels. Likewise, high potassium applications were favorable to flowering when iron levels were low. Czerski, Kulacinska, and Jankowska (1977) grew potatoes under 19 hours photoperiods in flow hydroponics under optimal mineral nutrition and light intensity. These conditions were very favorable for growth and had positive effects on the amount of flowering and its duration as well as on the number of fruits and seed. Weinheimer and Woodbury (1966) conducted studies to determine the effect of grafting as well as the influence of Solanum rootstocks on flowering, fruit set, and seed number when grafted with scions of the Russet Burbank cultivar. They found that grafting per se had no effect on flowering and fruit set. However, when Solanum maglia was used as rootstock, it increased flower number, fruit set and number of seeds. Girdling, excision of stems, grafting of other similar techniques are assumed to promote flowering by restricting downward transport of metabolites into the roots and/or tubers. Evidence in the literature does not support such assumption.

Pollination

Pollen germination can begin within half an hour of incubation on artificial media and reaches a peak in 2 to 8 hours. The speed of germination and pollen tube growth rate depend primarily on the germination medium and temperature. The optimum temperature for pollen germination in vitro is between 15 to 20°C, while temperatures above 25°C or below 10°C are inhibitory (King and Johnston, 1958; Bienz, 1958). Of the several media for pollen germination that have been recommended, the medium developed by Mortensen, Peloquin, and Hougas (1964), is the most widely used. The medium is composed of 20% sucrose, and 500 ppm boric acid. King and Johnston (1958) used a simple media composed of 14-16 g sucrose, 2 g agar and 100 ml water adjusted to pH 5.2. In this medium, germination rates were remarkably low presumably because of the omission of boron from the medium. Saini and Joshi (1975) recommended a complicated liquid medium for germination and tube elongation which contains 15% sucrose, 2.5 ppm $Ca(NO_3)_2$, 1 ppm H_3BO_3, 100 ppm cystine, 0.75 ppm lysine, 0.005 ppm glutamic acid, and 20 ppm gibberellic acid or 0.2 ppm indole acetic acid. According to Saini and Joshi no germination occurs in distilled water and very poor germination and tube elongation were obtained in 15% sucrose medium without other additives.

Pollen storage

Storage of pollen is sometimes necessary to facilitate crossing when both parents are not flowering at the same time or at the same location. The work of Kesseler (1930) and Kawakami (1934) showed that potato pollen can be stored for 10 to 14 days under dry conditions (15-20% RH). Beamish (1954) found that storage in a refrigerator can prolong pollen viability, while King (1955) stored pollen for about a year without viability loss at -30°C. Howard (1958) stored pollen of four cultivars at -20°C after the anthers had been dried overnight at 30°C or over silica gel. The viability of pollen stored for 11 months was no different from that of fresh pollen. Weatherhead et al. (1978) was able to store pollen for 9 months at -196°C without a decrease in viability whereas at -20°C germination was less than 1% after 9 months. For short-term storage, Tandler (1978) transported pollen in a thermos flask with dry ice at -80°C without loss of viability. Blomquist and Lauer (1962) emphasized the importance of drying anthers before pollen storage at low temperature.

Fruit set

Fruit set often does not take place even when conditions are ideal for flowering suggesting that the necessary conditions for flowering are not necessarily those that are optimum for some or all processes from pollination until fruit development. During the overcast, cool and winter days of Lima, little flowering can be observed on plants known to flower profusely under different conditions. In addition, of the few flowers that do develop most abscise prematurely. The poor flowering could have resulted from the relatively low temperatures and light intensities and short days which are conducive to good tuberization. On the other hand, flower abscission may have resulted from one or a combination of factors such as lack of insect pollinators, poor pollen viability, cool temperatures for pollen germination and fertilization. It could also have resulted from competition between tubers and flowers for a limiting factor.

During winter months in Lima, hand-pollinated flowers also abscise from plants that normally pollinate with ease, while pollination on similar plants succeed in the screenhouse suggesting that outside temperatures are too low for pollination. Flowering and fruit set improves in the spring coinciding with light intensity and temperature rise during the day and the cool nights. The improvement of fruit set may have also resulted from the increased activity of insect pollinators. During the hot summer months in Lima and Yurimaguas, some flowering occurs but fruit set is rare presumably because of the persistent high temperature effect on pollen viability and fruit set (Bienz, 1958; King and Johnston, Simmonds 1958; Young, 1923).

Premature blossom and fruit abscission can be a problem under glasshouse conditions in some cultivars and under certain environmental conditions. To overcome such problems, McLean and Stevenson (1952) suggested the use of mechanical stem girdling or growing cut, flowering stems in nutrient solutions. They speculated that the success of these methods resulted from carbohydrate accumulation above the point of constriction on the whole plant or in the cut stem. The application of growth regulators (.01% indole butyric acid in lanolin or 0.4% indole butyric acid with 0.1% chloro phenoxy acetic acid in lanolin) to the pedicel after pollination prevented flower and fruit abscission. Chalyuk (1975) was able to improve fruit set in the monsoon climate of the Soviet far east by repeated pollination at night when temperature was 15-20°C augmented by 0.5% indole acetic acid in lanolin paste application to the flowers. Similar results were obtained by Zafar (1955) by spraying plants with growth regulators. Patterson (1953) was able to obtain excellent fruit set from the variety Russet Burbank by growing plants under 18 to 19 hours photoperiod and 20°C during the early stages of plant growth and at 10 to 15°C when flowers were visible.

To improve flower retention and fruit set McLean and Stevenson (1952) and Peloquin and Hougas (1958) used the "milk bottle" technique in the greenhouse. The method consists of placing cut stems with unopened inflorescences from field grown plants in milk bottles containing tap water or nutrient solutions. Flowers are pollinated the usual way and the fruits are harvested at maturity. Of concern in using this method is the possible poor quality of seed that can be obtained from fruits that develop under inadequate supply of mineral nutrients and limited photosynthates.

Fruit harvest and seed extraction

In most cultivated potatoes, berries reach full development after about 6 weeks from pollination and at that stage seeds are

fully dormant and well developed (Simmonds, 1963b). Seeds from prematurely harvested fruits are less dormant and less viable than seeds extracted from fully developed fruits. The effect of berry size on the quantity and quality of seed was investigated by Rodiionova and Kogut (1975). They found a positive correlation between berry size and seed number, however, no correlation was found between berry size and seed size. No information is available in the literature on the effect of environmental conditions on potato fruit development and maturation before and after harvest. In most laboratories, fruits are allowed to ripen until soft at ambient temperature. The need for this period of post-harvest fruit ripening, its duration, and the optimum environmental conditions under which it should take place are not known. These factors however have been shown to have strong effects on seed dormancy and germination of solanaceous crops (Gutterman, 1978).

Recent work in our laboratory showed that temperature during fruit ripening has an effect on the degree of seed dormancy. Seed from three clones had higher degree of dormancy when obtained from fruits ripened at 15°C for about a month than when ripened at higher temperatures. (International Potato Center, 1981).

Small quantities of seed can be extracted by crushing fruits by hand and separating seed from pulp by repeated washing with water and sedimentation. When handling large quantities of fruits, mechanical crushing in a food blender can be done provided that the blender is operated at low speed to avoid seed damage (Simmonds, 1963a; Lauer et al., 1985).

Seed dormancy

The length of seed dormancy is variable and depends on the cultivar and environmental and cultural conditions under which fruit development and ripening take place. The latter factors have not been fully investigated in potatoes, but they are known to be important in other crops (Austin, 1972). Srinivasacher and Dwived (1959) and Simmonds (1963b) reported that seed of diploid cultivars have less dormancy than seed of tetraploid cultivars. Freshly harvested seed of most potatoes are dormant although some unpublished reports indicate that some seed can germinate after extraction from fruits provided that they remain moist. According to Simmonds (1963b) the intensity of dormancy increases with fruit development and reaches a peak after 6 weeks from pollination, which is in line with results of Haynes (1954).

Seed dormancy can be effectively ended by soaking seed for 24 hours in 1500 ppm solution of gibberellic acid (Fischnick and Grim, 1958; Spicer and Dionne, 1961; Shu-Lock and Erickson, 1966; International Potato Center, 1980).

Storage and seed longevity

A number of studies on the conditions for storage of true potato seed indicate the ease by which they can be stored. Wollenweber (1942) and Haig (1952) stored potato seed at room temperature and obtained adequate germination after 13 years, while Simmonds (1968) reported that seed viability begins to decline in 7-8 years and little viability remains after 11-12 years. In a long-term storage experiment, Howard (1969, 1975) found that seed stored in paraffin-sealed glass tubes at 5°C retained a mean of 79.6% and 71.5% germination after 15 and 20 years, respectively. Ross (1969), predicted that a germination of more than 75% can be obtained after 15-20 years of storage at 3-4°C. Barker and Johnston (1980) found that seed of S. tuberosum can be stored without stringent conditions with good germination for 15 years. Subramanyan (1971) obtained more than 70% germination after 10 years of storage at room temperatures fluctuating between 5-6°C and 42-45°C. Unfortunately, in all of the above studies, seed moisture content was not determined at the beginning of storage. The availability of such information is important in view of the strong interaction between seed moisture and storage temperature and its effect on seed viability. Although good germination was obtained following long storage without special efforts to reduce seed moisture content or the storage temperature. The possibility that such unfavorable storage conditions can affect seedling vigor and genetic stability should not be overlooked (Roberts, 1972).

Lange et al. (1979) reported that short-term storage of potato seed can be achieved at 2-3°C and 30% relative humidity. However, for long-term storage they recommended drying seed to 5-6% moisture content and storage at -10°C. Under these conditions they predicted seed viability after 20 to 30 years. Hinze et al. (1975) working with seed of six Solanum species found that storage temperatures ranging from -20°C to 20°C had negligible effect on seed viability after 4 years as long as the seed moisture content was low.

Sadik and White (1982) proposed a simple method for reducing potato seed moisture content before seed storage. According to their method, the moisture content of 20 g seed can be reduced from 11% to the recommended safe level of 4 to 5% in about one week of storage over 30 g of freshly toasted rice with a moisture content of less than 1%.

Seed tolerance to high temperature

Potato seed when well dried can tolerate long exposures to high temperatures. Dry seed with moisture content below 4% can be exposed for more than one hour to dry heat at 100°C without significant decrease in germination (Sadik and Salazar, unpublished). Seed infected with potato spindle tuber viroid (PSTV) could not be freed by a 1 hour exposure at 100°C. The effect of such temperature treatment on seed-borne viruses, fungi, and bacteria has not been studied.

Seed germination and seedling development

It is generally accepted that the optimum temperature for seed germination is about 20°C although seed of some progenies germinate better at 15°C. Temperatures above 25°C and below 10°C are in general inhibitory to germination (Stier and Cordner, 1937; Sadik, 1979; International Potato Center, 1981; Steinbauer, 1957).

The effect of light on seed germination is not clear. Simmonds (1963a) working with diploids and tetraploids found that germination was delayed in the dark and that tetraploids were more inhibited than diploids. Bedi et al. (1979), working with four breeding lines of seed, found that germination in continuous light was lower than in the dark at 7°C and 10°C while at 20°C germination in continuous light was slightly better than in the dark. Porter and Clark (1979) working with seed of Solanum aviculare and S. laciniatum stated that fluorescent light stimulated both the rate and extent of germination. Litowski and Rykaczewska (1975) found that germination is more sensitive to blue light than to others.

Because of seed heterozygosity, lack of uniformity of seed germination, seedling emergence and vigor are problems of practical importance. They can be serious problems, especially when seed is sown under high temperatures and in soil of poor physical and fertility characteristics. At the International Potato Center, high temperatures during germination and seedling emergence are reduced by providing 30% shading to the nursery bed and by keeping soil well watered during the first three weeks after sowing. Research at the International Potato Center (1980, 1981) indicated that a 1:1 mixture of sand and peat moss is an excellent substrate for germination and seedling development, especially when it contains, 100, 200, 100 mg/kg mix of PNK, respectively. Volcanic soil was successfully used as the sole substrate for the preparation of nursery seed beds in Rwanda (International Potato Center, 1981). Sand alone or other substrates low in organic matter are not suitable because of their low moisture holding capacity. In areas of high salinity, the sand used in seed bed preparation should be well washed with water. Seed bed watering should also be thorough to avoid soil salinity which can drastically affect germination and, especially seedling growth (unpublished results).

Transplanting "shock"

Potato seedlings are sensitive to the trauma of transplanting. Transplanted bare-rooted seedlings have been shown to require 19 days to recover their original growth rate before transplanting (International Potato Center, 1981). To reduce the severity of transplanting shock it is essential to raise vigorous seedlings in the nursery bed. Furthermore, seedlings should be well hardened before transplanting by withholding the rate and frequency of watering and by exposure to full sunlight a week before transplanting. Shading of seedlings in the field by companion crops, straw or other objects has been found helpful in increasing seedling survival and growth (International Potato Center, 1981). Soil mulching with straw or reflectants such as gypsum applied around seedlings at transplanting to reduce soil temperature and conserve soil moisture can improve seedling survival and growth under field conditions (International Potato Center, 1981).

A soil mix block-maker has been used successfully to reduce transplanting shock (International Potato Center, 1981). In this system blocks of soil mix are formed and seed is sown in each block and the seedlings are later thinned to 3 per block. By this procedure, seedlings are provided with good medium for growth and the transplanting shock can be significantly reduced. The practicability of this method for small farms is under investigation.

Population density

A potato seedling has one main stem which later produces lateral branches at nodes

too high for effective tuberization. Since the number of main stems per plant is an important component of yield, it is necessary then that an optimum number of stems per unit area of land should be achieved when potatoes are produced from true seed. Several approaches have been investigated. The most obvious approach was to increase the number of seedlings per unit area either by transplanting several seedlings per hill or by planting seedlings at closer spacing. Maximum yields were obtained when 3 to 4 seedlings were planted per hill or when planted individually within 30 cm of row space. This approach obviously increases the cost of production because more seedlings have to be produced in the nursery and transplanted in the field. The possibility of stimulating lateral branching at low nodes by early clipping of the seedling growing point was investigated in a preliminary trial and the results were encouraging. A search for chemicals that can induce branching at an early stage of seedling development is under investigation.

Pests and diseases

In general, insect pests and diseases that attack potatoes grown from true seed are the same as those generally found on potatoes from seed tubers. Because of their tenderness, plants from true seed are more likely to be injured by insects and diseases.

Cutworms are the most damaging to young seedlings in the field. Carbamates applied as side dressing in soil are non-phytotoxic and offer good protection in desert areas. In tropical areas with high rainfall, damage by pests such as leaf beetles, cutworms, aphids, leaf hoppers, leaf miner flies, potato tuber moths, etc. could be controlled effectively by the use of foliar sprays, as soil insecticides are not effective under such conditions (International Potato Center, 1981).

Soil-borne pathogens can cause considerable damage during seedling emergence in the seed bed and after transplanting in the field. The most serious pathogens are Rhizoctonia solani, Sclerotium rolfsii, and Phythium spp. Fungicides, such as Benomyl, that can be absorbed by roots can give protection when applied to the soil. To prevent fungal damage to transplanted seedlings in the field, 0.15% solution of pentachloronitrobenzene (PCNB) sprays in the furrow and 0.1% Benomyl applied to the seedling base immediately after transplanting have given good control to fungal diseases. Fungicides applied as seed dressing at sowing have been found very effective in controlling fungi.

Potential yield

Yields reported in the literature show a progression with time as a result of the development of better plant management practices and the availability of better seed progenies. Potential yields from true seed can be very high when growing conditions are optimal for potato production. In the Southwest Mountain Region of China, where ideal temperatures and rainfall are present, yields of up to 38 tons per hectare have been recorded (Li and Shen, 1979). Bedi et al. (1979) obtained yields ranging from 20.2 to 47.2 tons per hectare from direct sown seed. In another experiment they compared yields from transplants and direct sown seed, and found that the mean total yield of 10 seed progenies ranged from 15.6 to 39.6 (mean 26.1) tons per hectare by direct seeding and 9.1 to 35.8 tons per hectare (mean 21.7) by transplanting. In another year, when yield and climatic conditions were not conducive to direct field sowing, very low yields were obtained by direct seeding. In an experiment conducted in San Ramon and Lima, Peru, Malagamba (unpublished) compared the total and marketable yields of 75 hybrid seed and open-pollinated progenies by transplanting in May 1981, which coincided with the cool part of the year in each place. Table 1 shows the yield of the top 7 seed progenies. It should be noted that a large portion of the non-marketable tubers can be used for planting provided that adequate insect control measures are adopted during plant growth to minimize virus infection in the field.

Table 1. Total and marketable yields of the top seven seed progenies in two locations in Peru (ton/ha).

Progeny	San Ramon		Lima	
	Marketable	Total	Marketable	Total
Atzimba X 51.7 X +Y.1	40.0	44.8	16.9	24.4
LT1 X 14X + Y.4	34.9	38.3	19.6	24.2
LT2 X DTO-28	27.5	29.2	-	-
Atzimba X DTO-28	26.8	30.9	-	-
41.79 (o.p.)	25.5	28.9	38.2	41.9
104.10 (o.p.)	23.2	29.1	34.8	38.7
DTO-33 (o.p.) (control)	16.6	21.2	9.2	12.6

Kidane-Mariam (unpublished) evaluated the yield of 40 seed progenies in September 1981 (late winter) in Lima. In addition to an average yield of 36 ton/ha of marketable tubers, there was a high degree of tuber uniformity in respect to size and shape.

These reported yields illustrate the high yielding potential of potatoes grown under good soil and climatic conditions from seed. It is expected that such yield potentials will increase with better plant management and breeding and selection of better seed progenies. The potential yield of improved progenies may equal that of cultivars under similar growing conditions.

FUTURE RESEARCH

Potato production from true seed is new and, therefore, there are many problems and gaps in our knowledge. Below is an attempt to highlight important problems that require urgent research to facilitate the use of TPS for potato production.

Flowering and fruit set

Most studies on flowering, fruit set and seed production dealt with cultivars of Solanum tuberosum which were bred and cultivated in temperate zones under cool conditions and long days. On the other hand, little attention was given to flowering studies on Solanum andigena.

Techniques to induce or promote flowering and seed set by such methods as the 'brick' method, stolon pruning and grafting are satisfactory for producing small seed quantities such as those needed by breeders. However, these methods are not reliable and economic for commercial seed production.

To improve the potential acceptance of true seed for potato production, seed should be readily available and at reasonable prices. Thus, simple and inexpensive methods for seed production should be discovered. This will involve identifying the environmental factors necessary for flowering and the development of simple and practical methods for its induction. The environmental factors affecting pollen quality, pollination, fertilization and fruit set under field conditions should be studied.

Seed quality

Seed germination, seedling establishment and vigor of cultivated plants are directly or indirectly affected by genetic factors and the environmental influences which have acted on the seed before and after its harvest. These include factors such as the nutrition of parent plant, rainfall, soil moisture, ambient temperature during fruit and seed development, and seed storage conditions after harvest. How these factors affect the performance of potato seed at the nursery and field levels is not known. In view of the numerous problems that we face with potato seed germination and seedling vigor, it seems necessary that thorough studies should be conducted on the important environmental factors under which seed production takes place and their effects on seed quality.

Seed weight, volume, density, and moisture content have been found to affect the speed and uniformity of germination in many crops. Preliminary studies in our laboratory confirm such effects in potatoes and, therefore, such studies should be pursued. The effects of embryo types shown by Upadhya, Chandra, and Sharma (1981) should be studied to ascertain their effects on seedling vigor and ultimate yield.

Seed germination

The environmental factors necessary for optimal germination of seed of most potato cultivars are well known. The speed and uniformity of germination can be very low at non-optimal temperatures which is frequently the case under field conditions, especially in medium or low elevation tropical countries. Therefore, research should be directed to breed seed progenies for good germinability at temperatures between 25 to 30°C. In spite of the fact that soil temperatures above 35°C can be experienced for some durations during seed germination, the effect of such high temperature exposure can be offset by exposures to low temperatures, especially at night. Concomitant with breeding and selection for germination at high temperature, other laboratory and field techniques should be evaluated for improving seed germination at high temperature such as pre-germinating seed before field sowing and simplified fluid drilling techniques.

Seedling emergence and development

Seedling vigor of potatoes is somewhat weaker than that of other solanaceous

plants. Their growth is sensitive to adverse temperatures and poor soil fertility. To ensure better chances for seedling survival in the field, good seedlings should be used, which are characterized by having good root systems, stocky upright stems, healthy vigorous leaves and without premature stolon or tuber formation. To achieve such characteristics, formulations of seed bed mixes of proper physical and chemical composition to ensure rapid and healthy growth before transplanting are needed. Furthermore, studies should be conducted to determine the optimum environmental conditions for seedling growth. Studies should be also conducted on the possible beneficiary effects of growth regulators such as B-9 and Cycocel on seedling growth and transplant quality in view of their beneficial effects on seedling growth of other solanaceous crops.

Direct field sowing vs. transplanting

Potato seeds are small and germinate slowly over a narrow range of temperatures. Seed sown directly in the field have little chance to germinate and develop into strong seedlings, except under optimal conditions of soil structure and moisture, and temperature conditions. Because of these precise requirements, the use of transplants and seed tubers derived from true seed have been suggested as practical methods for growing potatoes from true seed. Although considerable success has been achieved at the experimental level in growing potatoes by transplanting, there is fear that in certain areas the high labor inputs necessary to produce, transplant, and care for about 100,000 seedlings per hectare, can undermine the basic reason for the use of true seed as substitute for the costly seed tubers traditionally used by potato growers. This suggests a need for research towards the development of practical and simple methods for direct field sowing. The difficulties of establishing a potato crop by direct sowing are unlikely to be any greater than those which vegetable growers experience in establishing crops directly from seeds. A wealth of knowledge and experience is available on direct field sowing of small-seeded crops, which can be used to develop appropriate direct sowing techniques for potato growers in developing countries. Fluid drilling sowing techniques have been commercially used in the UK for sowing small-seeded crops such as lettuce, carrot, celery, parsnip, and tomatoes. In California and Florida, tomatoes have been grown for many years using direct seeding. It is felt that such techniques, with appropriate modifications, can be used for field sowing of potatoes in the future. When this becomes a reality, the benefits of true seed may far exceed our present expectations because of further reductions in production costs.

In reality, neither transplanting nor direct sowing will be used to the exclusion of the other. In Britain and North America, lettuce and tomato growers practice both methods of planting depending on their circumstances. It is important to remember that tomato seedlings are transplanted by hand into seed beds at densities of up to 1,000,000 plants/ha in North America and North Europe. This illustrates that transplanting can be used economically even in areas where labor is expensive. In developing countries with high populations and high rates of unemployment, growing potatoes by transplanting can be an indirect solution to chronic unemployment problems; however, these high labor inputs would certainly increase the price of potato and make it harder to realize the ultimate goal of providing the potato as an inexpensive source of nutrition. This goal, in our opinion, can only be achieved by breeding progenies with high yields and by lowering the cost of production by substituting true seed for seed tubers and establishing the crop by direct sowing instead of transplanting.

Seed pelleting

Pelleting of small seeded crops has been used to facilitate easy seed handling for precision planting. Another purpose for pelleting is to incorporate desirable additives to the coating medium to produce rapid and localized effects on the developing seedling.

Because of the smallness and size variability of potato seed, research should consider the feasibility of seed pelleting as an aid to sowing, germination, and seedling establishment, especially to facilitate direct field sowing. Of importance is incorporation of beneficial compounds such as slow release fertilizers, fungicides, nematicides, and systemic insecticides in the seed coating to help protect or invigorate emerging seedlings.

Seedling stem number

A large number of seedlings (100,000 per ha) have to be transplanted to increase stem number per unit area to achieve adequate yields. Because of the high cost on seedling production and transplanting, techniques should be developed to encourage branching at lower nodes of seedlings. Killing the apical growing point of the seedling by pinching or by chemical sprays has been successfully used in other plants and deserves experimentation with potatoes.

Presently, seedlings are planted singly 10 cm apart or 3 - 4 seedlings at 30 cm spacing in rows 90 cm apart. Research is needed on population density as well as on the proper pattern of planting to maximize yields.

Hybrid and open-pollinated progenies

An extensive list of hybrid and open-pollinated seed progenies have been evaluated at the International Potato Center in Peru and by the Templeton Plan Breeders in New Zealand. In general, hybrid progenies are superior to open-pollinated progenies in regard to seedling vigor, yield, size, shape and color of tubers. However many open-pollinated progenies are equally good.

Hybrid seed production requires skillful and costly management, while seed from open-pollinated plants is easy to obtain and, thus, is probably more relevant to backyard home gardeners who grow potatoes for family consumption. The use of hybrid seed will probably be the choice for large farming operations because of better plant vigor, yield, and tuber uniformity.

Because of the high technical knowledge and high cost necessary to produce hybrid seed, it is expected that it will be produced by private seed companies or governmental agencies.

Research is necessary to find effective and simple methods for hybrid seed production, which should include finding chemical gameticides to alleviate the need for hand emasculation of anthers as well as better techniques for pollen collection, storage, and pollenation on large scale.

Apomictic seed production

Hermsen (1980) proposed to breed for apomixes in potatoes to obtain genetically uniform seedlings. Irikura (1981) induced apomictic seed formation in diploid and tetraploid potato cultivars with 2, 4-D sprays on emasculated flowers. Iwanaga (1982) suggested a two step approach for obtaining apomictic seed: 1) induction of apospory and 2) chemical induction of autonomous seed development.

The induction of aposporous apomictic seed can be of great value to potato production from true seed. Aposporous true seed is genetically identical to the parent plant and, thus, the seed can be referred to as clonal true seed. Some of the advantages of such seed are:

Production of uniform plants which should overcome one of the major drawbacks of potato production from true seed.

Virus-free plants can be obtained from virus-infected plants by inducing aposporus seed. This can alleviate the need for freeing infected plants by tissue culture and thermotherapy techniques.

Aposporous seed can be used more efficiently for the maintenance and distribution of germ plasm maintained and distributed in vegetative form. The use of aposporous seed for this purpose can also reduce disease transmission from one generation to another.

The advantages of using apomictic seed for research of potatoes are great. However, from a practical point of view much research is needed to facilitate the induction of apomictic seed by simple and efficient methods. A successful and practical method should facilitate the production of large quantities of seed at reasonable costs for potato growers.

CONCLUDING REMARKS

The ultimate goal of research on potato production from true seed is to develop technologies for potato growers in developing countries based on simplicity, low production cost and high yields of acceptable quality.

To achieve such objectives research during the next two decades should concentrate on finding solutions to priority problems to ensure the formulation of appropriate technologies. Among the important components of such technologies are:

Development of agronomic systems compatible with growers, farming systems and socio-economic factors.

Development of seed progenies with good plant vigor, high yields, early maturity, tuber uniformity, acceptable quality, and perhaps resistance to economic pests and diseases. Such progenies should be from parents that flower and set fruit profusely to result in the availability of inexpensive seed.

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NEW DISEASE ELIMINATION TECHNIQUES IN SEED PRODUCTION PROGRAMS

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Prior to 1900, it was widely believed that asexual propagation of potatoes by tubers was responsible for the degeneration and loss of vitality that was invariably observed with potato varieties over a period of years (Jones et al., 1981; Shepard and Claflin, 1975). As we now know these potato varieties were being contaminated with several tuber-borne pathogens, especially viruses, which reduced productivity. With the advent of the 20th Century, however, Dutch and German agriculturalists found that certain symptoms of degeneration as leaf curling and rolling, crinkling, and blotching were infectious and that elimination of affected plants would control these maladies.

Seed potato improvement programs comprised of participating seed potato growers and an official certifying agency soon followed (Jones et al., 1981; Seed Production Technology, 1974; Shepard and Claflin, 1975). The original charges given to these seed improvement programs were (i) to maintain variety purity and (ii) to establish visual tolerances for known infectious diseases. Although elaborate seed production programs have been developed in many countries since that time, the original premises are still the foundation for all sound programs.

It is understandable that, as our knowledge about the pests which caused potato diseases increased, our perspective of how to control the diseases changed. For example, post-harvest seed testing developed largely because aphids were demonstrated to be vectors of the potato leaf roll virus (PLRV) (Hille Ris Lambers, 1972). Vector migration and, hence, PLRV transmission often occurred too late in the growing season for infected plants to develop disease symptoms. Tests to establish seed quality before the next growing season were essential and various "growing-out" and tuber assays were developed to meet this need. As methods to detect plant viruses improved, it became evident that many established and economically important potato varieties were universally infected with one or more latent viruses (Beemster and Rozendaal, 1972). Pioneering research by Kassanis (1957) on tissue culture techniques for virus elimination and by E. and D. H. M. Van Slogteren (1957) on plant virus serology for virus detection is the base on which most of the new disease elimination techniques rest. In North America, impetus to utilize these techniques did not develop until research scientists in Canada demonstrated significant yield losses due to the latent viruses S and X, utilized thermotherapy and meristem-tip culture techniques to obtain virus-free potato plants, and then made these plants available to seed improvement programs (Goodwin et al. 1980; Mellor and Stace-Smith, 1977; Wright, 1970).

Recent advances in disease elimination techniques will be discussed first by considering individually the techniques which have been utilized to control viroids, viruses, bacteria, and fungi and then by providing a perspective of how disease tested stocks can be quickly and efficiently incorporated into seed production schemes.

VIROID. The potato spindle tuber viroid (PSTV) is a unique pathogen comprised of only ribonucleic acid (Diener, 1979). The lack of pathogen-associated protein has rendered standard plant virus serological approaches useless for detection and an attempt to produce an antiserum which would be specific for the unusual RNA was not successful (Pfannenstiel and Slack, 1981).

Visual detection is hampered by the existence of cultivars tolerant to PSTV infection and by mild strains of PSTV (Pfannenstiel and Slack, 1980). Although thermotherapy plus meristem-tip culture have not been effective for the elimination of PSTV from stocks, Lizarraga, et al. (1980), demonstrated recently that low temperature treatments plus meristem-tip culture were effective.

In 1975, Morris and Wright reported that PSTV could be detected by polyacrylamide gel electrophoresis (Morris and Wright, 1975). Several modifications have been introduced to make the testing procedure shorter, more sensitive, and appropriate for mass indexing in seed production programs (Morris and Smith, 1977; Pfannenstiel et al., 1980; Schumann et al., 1978.

Owens and Diener (1981) reported a nucleic acid spot hybridization test for PSTV detection. The technique is based upon the hybridization of DNA complementary to PSTV (cDNA) with PSTV on a nitrocellulose membrane. Although the technique requires four days for completion, it is reported to be about ten times more sensitive than polyacrylamide gel electrophoresis and it is suitable for incorporation into testing schemes in which large numbers of samples are being processed.

VIRUSES. Elimination of potato viruses from stocks by meristem culture is reviewed in detail by Mellor and Stace-Smith (1977). Recently, Kaiser expanded the heat therapy work of Kassanis (1949) on PLRV and reported that alfalfa mosaic virus, potato leaf roll virus, and tomato black ring virus could be eliminated from potato tubers by incubation at 37°C for 3-6 weeks alone (Kaiser, 1980). This procedure is being used in Kenya on stocks which will be distributed to seed improvement programs in East Africa.

There are three sensitive serological techniques that have been of interest recently in evaluating seed potato stocks for freedom from specific viruses. They are:

(i) Enzyme-linked immunosorbent assay (ELISA) or enzyme immunoassay (EIA) which Clark and Adams (1977) introduced for the detection of plant viruses. ELISA is able to detect 1-10 ng/ml of virus which is about 1000 times more sensitive than established agar-gel diffusion techniques. The technique requires two days to complete but quantitative information can be obtained and large scale sampling operations are feasible. Test sensitivity has made this technique extremely useful for detection of plant viruses which are present in low concentration in host tissues, e.g., to detect the phloem-limited PLRV (Caspar, 1977; Clarke et al., 1980; Gugerli, 1978). Sample preparation for ELISA has been reduced as a time-consuming step by the introduction of leaf-disk assays (Romaine et al., 1981) and equipment for expressing leaf and tuber saps for assays (Gugerli, 1979). A potential problem for ELISA testing is that the technique may be too specific to detect all strains of a particular virus. In 1979, Koenig, at al., reported that Andean potato latent virus (APLV) could be separated into three strain groups and that ELISA was strain-specific by group while the latex agglutination test (LAT) detected strains in all three groups (Koenig et al., 1979). The authors suggested that a multivalent antiserum would permit ELISA testing for APLV in seed production programs. Also, in 1981, Duffus indicated that beet western yellows virus (BWYV) could induce leaf roll symptoms in potato and that several BWYV serotypes were found in potato that differed from each other and from PLRV in serological reactions (Duffus, 1981). Although the question of reliable detection of PLRV strains and PLRV:BWYV by serological techniques is raised, all 20 plants with leaf roll symptoms collected from the Florida Winter Test Plot in January of 1982 indexed positive in ELISA assays with a single PLRV antiserum produced by Dr. Stace-Smith, Canada Agriculture, Vancouver (Dr. E. Jones, Cornell, Personal Communication). The leaf roll samples were comprised of 14 potato cultivars representing 7 geographic areas. Also, Drs. P. Gugerli of Switzerland and B. D. Harrison of Scotland have indicated that PLRV strain detection by ELISA has not been a problem in their experience (personal communication). It is interesting to note that at least four commercial enterprises for selling potato virus antisera and/or ELISA kits have been initiated recently as a result of the enthusiasm generated by the emergence of the ELISA technique coupled with the importance of virus detection as a quality determinant in seed potato production.

(ii) The LAT has been utilized by Khan and Slack (1978, 1980) to screen stocks for the potato viruses S and X (PVS, PVX) in a seed production program. The advantages of LAT are that assays are simple to perform and results can be obtained within 15 minutes and that LAT is about 100 times more sensitive than standard agar-gel diffusion techniques. Although LAT is an excellent technique for screening stocks for most potato viruses, the tenfold increase in sensitivity obtained with ELISA is essential for PLRV detection and the technique is not applicable when quantitative results are desired. CIP has utilized LAT to detect PVS, PVX, PVY, APLV, and Andean potato mottle virus (APMV) and has distributed sensitized latex to these viruses to 15 National Potato Programs throughout the world. (CIP Annual Report, 1980).

(iii) The serologically specific electron microscopy (SSEM) technique was introduced by Derrick (1973). SSEM can be used to quantify results and has the same relative sensitivity as ELISA. SSEM is less suitable than ELISA or LAT for mass indexing programs because initial and operational costs are high and well-trained technical support is essential. Roberts, et al. (1980) used SSEM to demonstrate that PLRV and BWYV are serologically related.

BACTERIA. Tuber-borne phytopathogenic bacteria have received considerable attention in seed production programs. Many programs have incorporated stem cutting or other related procedures in an effort to eliminate these tuber-borne bacteria. The most important of these bacteria are Corynebacterium sepedonicum which causes the ring rot disease. Erwinia carotovora subsp. atroseptica (Eca) and carotovora (Ecc) and E. chrysanthemi (Echr) which cause the blackleg and soft rot disease, and Pseudomonas solanacearum which causes the bacterial wilt or brown rot disease. In general, the diagnostic techniques which have received the most attention for the detection to these bacteria are selective media and serology. Since the ecology of these bacteria influences perpetuation in stocks, these bacteria will be discussed individually with the appropriate diagnostic techniques being included for each bacterium.

(i) Corynebacterium sepedonicum is tuber borne but not soil-borne. The pathogen persists in contaminated stocks or on contaminated surfaces (equipment, burlap sacks, etc.). Traditionally, ring rot diagnosis has been based upon the demonstration of characteristic Gram positive bacteria in symptomatic plant or tuber tissue. Detection and diagnosis, however, are difficult when ring rot is latent in potato tissues or when excessive tissue breakdown is evident. Although Snieszko and Bonde (1943) reported that incorporation of potassium dichromate into a medium would selectively favor growth of C. sepedonicum over other bacteria, a widely used selective medium has not been developed. Recently, Slack, et al., reported the specific detection of C. sepedonicum in potatoes with the LAT, agar-gel diffusion, and indirect immunofluorescent antibody stain (IFAS) serological tests (Slack et al. 1979 a and b). De Boer and Copeman (1980), however, reported cross-reactions with other bacteria in IFAS tests and noted that although IFAS was useful as a confirmatory test, IFAS should be questioned as a diagnostic assay.

(ii) The soft rot erwinias are important primary pathogens of growing plants as well as destructive pathogens of stored tubers (Perombelon and Kelman, 1980). Although considerable controversy exists over whether or not the soil is an important inoculum source, there is little doubt that Erwinia- contaminated stocks have more field and storage quality problems than stocks produced from stem or leaf bud cuttings until recontamination becomes evident. In 1974, Cuppels and Kelman reported crystal violet pectate (CVP) medium as a useful selective medium for the isolation of soft rot bacteria from soil and plant tissue (Cuppels and Kelman, 1974). Recently, Phillips and Kelman incorporated 0.01% sodium dodecyl sulfate into the CVP medium to enhance selectivity in the isolation of E. carotovora from insects and they developed a tetrazolium chloride plate method based on the utilization of alpha-methyl glucoside to differentiate between Eca and Ecc (Phillips and Kelman, 1982). Serological relationships among Eca, Ecc, and Echr have been explored and considerable antigenic heterogeneity has been demonstrated (Perombelon and Kelman, 1980). However, only two sero groups have been demonstrated for Eca and direct FAS has been used to selectively screen for the presence of Eca potato plants and tubers and insects (Allan and Kelman, 1977). The combined use of selective media and serological techniques has been an effective approach for monitoring the health status of potato stocks.

(iii) Pseudomonas solanacearum is known to persist for long periods in soil but the reasons for the soil-borne nature of this organism are still being examined (Jackson and Gonzalez, 1981, Quimio and Chan, 1979). Since the bacterium is active only under relatively warm conditions, seed crops in tropical regions of the world are typically produced in the cooler highland climates (French, 1979). Under marginal climatic conditions, however, latent infections may occur (Ciampi et al., 1980; French, 1979). Although stocks free from P. solanacearum may show

a high incidence of disease when planted in infested soils under warm conditions, it is important that disease-free stocks be utilized to minimize disease incidence in infested areas and to prevent introduction of the bacterium or new strains of the bacterium into other areas. In 1977, Gonzalez estimated that a 1% infection rate in stocks could be determined with a 200 tuber sample by storing the sample at 28°C for 3 weeks (Gonzalez, 1977). After storage, tubers not showing external symptoms were cut at the stem end and held in a humid atmosphere to observe for vascular ooze. In 1978, Fucikovsky reported that filter paper could be impregnated with 1% N,N-dimethyl-p-phenylenediamine (or tetramethyl form) and that an oxidase test could be performed by pressing the cut stem-end of tubers against the filter paper for 10 seconds (Fucikovsky, 1978). The development of a red stain on contact with the vascular bundles of the tuber was diagnostic for P. solanacearum. Sensitivity was reported as 9×10^2 cells/g tissue. More recently, Ciampi and Sequeira (1980) reported an enrichment technique and Granada developed a selective medium to increase detection of P. solanacearum. The selective medium developed by Granada is based upon the addition of antimicrobial compounds to the tetrazolium chloride medium of Kelman (Granada, 1981). These latter diagnostic techniques should be useful to detect latent tuber infections. Additionally, the selective medium should be useful for monitoring soil populations of P. solanacearum. Several serological studies have been made, but the conclusions reached have been contradictory and current utility for diagnostic purposes is limited at best (Coleno et al., 1976).

FUNGI AND OTHERS. Although potato diseases incited by fungal pathogens are important limiting factors to crop productivity, new techniques have not been introduced to specifically monitor or eliminate contaminated stocks in seed production programs. Certainly the introduction of metalaxyl (Ridomil), a systemic acylalanine fungicide with curative properties, should be mentioned for the impact that it has on the control of both the foliar and tuber phases of late blight caused by Phytophthora infestans (Fry et al., 1979). Although races of P. infestans resistant to Ridomil have been documented and the future of this particular fungicide as a control agent is unclear, the immense benefits which can be derived from the careful use of systemic fungicides in seed production programs is evident. Problems encountered by seed production programs in the tropics may lead to increased disease elimination efforts, e.g. control of the soil-borne problems pink rot caused by Phytophthora erythroseptica Pethybr. and smut caused by Angiosorus solani (Barrus) Thirum. and O'Brien (syn. Thecaphora solani Barrus) was obtained by fumigating soil with either Dazomet or methyl bromide with a plastic cover for 10 days (CIP Annual Report, 1980). Additionally, latent infections with Fusarium spp. were observed to lead to a wilt incidence of 20-60% in 1980 in Sri Lanka when tubers were planted near sea level on Jaffna peninsula (M. Velupillai and E. French, unpublished). Soil temperatures at 10cm depth were 29°C day and 25°C night at planting and increased to 36°C day/30°C night in subsequent weeks.

Similar statements can be made for the control of nematodes and insects like the potato tuber moth. New approaches to control which may eventually supplement seed production programs are being evaluated, e.g., biological control studies on the root-knot nematode, Meloidogyne incognita, by the fungus, Paecilomyces lilacinus (CIP Annual Report, 1980).

MULTIPLICATION OF SEED STOCKS. Although the field multiplication of seed stocks for several generations without encountering contamination with one or more pathogens has not been demonstrated, the techniques to obtain selected seed stocks (nuclear stocks) which are pathogen-free now exist (Mellor and Stace-Smith, 1977; Slack, 1980). The goal of seed production programs is to increase these nuclear stocks by clonal propagation as rapidly as possible to enable commercial potato producers and consumers to benefit from their increased productivity and quality.

The protocol for generation and maintenance of nuclear stocks varies considerably among seed production programs. The mere visual identification and selected increase of the most vigorous plants in a field may result in greatly increased yields in some regions of the world. As the level of sophistication of the potato industry increases in a region, however, a concomitant rise in the level of sophistication of the seed industry also can be expected. In the most sophisticated programs, nuclear stocks are reselected and retested for freedom from specific pathogens annually (e.g., Slack, 1980). Since tissue culture systems for maintaining plantlets have been established (Henshaw et al., 1980; Westcott, 1981 a and b) some programs are now maintaining these valuable stocks in vitro as well as in the field. Since the prospects for contamination in tissue culture are diminished, tissue culture maintenance of stocks also is desirable for CIP and other programs interested in the international transfer of germ plasm (Roca et al., 1979). In Taiwan, the first generation stocks in the seed increase program are produced by in vitro tuberization (Wang and Hu, 1982).

Once nuclear stocks have been generated, rapid stock multiplication is of premium importance. Stem and leaf bud cuttings have been used in some programs for several years (Bryan et al., 1981; Lauer, 1977; Slack, 1980) and newer methods for rapidly multiplying stocks have been reported recently (Goodwin et al. 1980 a and b; Roca et al., 1979). Bryan et al. (1981) summarized many of the important concepts in the production and management of cuttings in rapid multiplication schemes. Rapid multiplication techniques are labor intensive and require special equipment and facilities, but they enhance stock quality by eliminating microorganisms and they can reduce the number of seed production generations.

Summary

The sophistication of seed production programs has increased dramatically in the past 15 years. The development and systematic use of new technology for obtaining and testing stocks for freedom from potato pathogens and for maintaining and multiplying these tested stocks has enabled this change to occur. It is expected that additional techniques will continue to be developed and utilized in the future. For example, increased specificity in the identification of bacteria might be expected by the development of monoclonal antibody systems (Hudson and Hay, 1980) and bacterial disease incidence might be minimized by inoculating plants or tubers with selected "growth-promoting" rhizobacteria (Kloepper et al., 1980). Certainly all techniques are not applicable to all programs and each program must select the level of sophistication that best meets its needs. It is suggested, however, that the continued emphasis on plant health techniques and programs is to the benefit of an increasingly larger segment of the World's populace.

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NEW APPROACHES TO BREEDING FOR THE POTATO FOR THE YEAR 2000

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Introduction

The ideas and facts that we consider most important and promising at present, will greatly determine the situation in the year 2000. This statement implies that we have to initiate to-day what we want to practice in the year 2000. Along the same lines of thinking we can go back 20 years in history when some important developments were initiated in potato breeding.

Twenty years ago:

Twenty years ago Hougas and Peloquin initiated their stimulating research on dihaploid potatoes. At present haploids are being used in breeding and research all over the world.

Twenty years ago Becker and his coworkers Skiebe, Jahr, and Stein demonstrated the potential of 2n-gametes for breeding diploid and all polyploid horticultural crops, including interspecific hybrids. These workers were not aware of the cytological mechanisms involved, but emphasized its regular occurrence in nature. Yet the most important mechanisms had been described already in the twenties and thirties, not only in apomictic species, but also in interspecific and intergeneric hybrids.

Peloquin and his associates focused the attention on the widespread occurrence and on the potential of 2n gamete formation in potato and described two basically different cytological mechanisms, first division restitution (FDR) and second division restitution (SDR).

A third important development 20 years ago was the initiation by Simmond (1961, 1966) of an adaptation programme using tetraploid and diploid cultivated potatoes from the gene center. A few years later Plaisted (1972), Haynes (1972) and Maris (unpubl.) took over Simmonds' approach, that in the meantime has proved to be a sound one.

When CIP was founded in 1972 these three developments have put a mark upon the breeding approach that CIP adopted at the start.

What do we know at present, in 1980?

The production of dihaploids through pseudogamy in autopolyploid potato has become a routine method and is being applied at most breeding research institutions. We know that breeding dihaploids within subspecies tuberosum may lead to beautiful clones, but yields are too low.

Including diploid S. phureja, S. stenotomum dihaploids from subspecies andigena and from Neotuberosum, and even wild diploid species, like S. chacoense, have not led and will probably never lead to superior diploid varieties, because diallelism is the maximum degree of heterozygosity in diploids (Bingham, 1980).

The pioneering work of Peloquin and coworkers at Madison, USA, has shown how excellent diploid clones can contribute their genotypes largely or even completely intact to the autotetraploid progeny via 4x-2x matings, when the diploids have the ability to produce 2n gametes through some kind of first division restitution mechanism. The superior vigor of the progeny may be ascribed to the high frequency of tetra-allelic loci and to favourable epistatic effects. However we have to keep in mind the following facts.

All large experiments for testing the feasibility of the FDR approach are based on a highly restricted number of diplandroid-producing FDR clones. I am referring to the experiments by Mendiburu, Mok and Peloquin, Wisconsin, U.S.A., by De Jong and Tai in Canada, by Erjefalt in Sweden, by McHale, Veilleux and Lauer in Minnesota, USA and by Sanford and Hanneman in Wisconsin, USA. These experiments have nicely shown the tremendous potential of the approach. But at the same time the weak point has become apparent: the narrow genetic base of diploids used, tracing back to few ssp. tuberosum dihaploids and a few clones from S. phureja.

It may be useful to formulate some requirements in relation to a more general practical application of this powerful tool.

1. The tetraploid and diploid parents should be complementary for horticultural traits and resistances to diseases, pests, and abiotic stress conditions.
2. The diploid parents should have the best possible mechanism of intact transfer of their genotypes. I will return to this subject.

In this connection I should like to advocate more international cooperation in breeding a broader population of advanced FDR clones that are adapted to different climates and latitudes and have a relatively stable diplandroid or diplogynoid production. In addition, research should be extended to the potential of other mechanisms than the (reduction + restitution)-mechanism of the Wisconsin clones of the early seventies and also to the possibility of manipulating them in breeding programmes.

Mechanisms of (nearly) intact transfer of genotypes

In the literature several cytological mechanisms that lead to FDR in plants, have been recorded. These are:

1. Semi-heterotypic division with reduced homologous pairing and the formation of a restitution nucleus during first division of meiosis (Rosenberg, 1927).
2. Pseudo-homotypic division, a first division abnormality with hardly any or no homologous pairing at first division and lack of second division (Gustafsson, 1935, Lamm, 1941, Hermsen and Ramanna, 1981).
3. Fused spindle mechanism, a second division abnormality (Karpechenko, 1927). It may occur in association with either normal pairing or with desynapsis during first division, as has been found in many interspecific hybrids (many references: see Harlan and De Wet, 1975), in monoploids (Ramanna, personal communication), but also in synaptic mutants (Iwanaga and Peloquin, 1979, Ramanna unpubl. results).
4. Premeiotic doubling followed by autobivalent formation (Hakansson and Levan, 1957). It has also been mentioned by Iwanaga (1980) and by S.L. Lam (1974).
5. Mitotized meiosis, in which first division is completely lacking (Gustafsson, 1935).

In the first three cases at least some gene recombination may occur; in the latter two cases there is no gene recombination at all.

Further details will not be presented here. Suffice it to state that in potato three types of FDR have been found with certainty:

a. Normal pairing in first division, fused (or parallel) spindles in the second.
b. Desynapsis in the first division, fused (or parallel) spindles in the second.
c. Pseudo-homotypic division.

It is not yet known, whether different genes control the second division abnormality (a, b) and the first division abnormality (c).

The importance of female 2n gametes for TPS production

Special attention should be paid to the formation of 2n gametes on the female side, particularly in view of the production of TPS. Iwanaga (1980) when working at Wisconsin, did a good piece of work in this field. In the years ahead an improvement may be expected of the methods for studying the development of megaspores. Ramanna has already improved the clearing technique of Herr (1971) for the observation of megasporogenesis in potato. Not all the details of meiotic stages can be seen, but it may become possible to establish conclusively:

1. whether a megaspore is developing from a tetrad or dyad.
2. whether a gametophyte is diplosporic or aposporic in origin. It might even become possible to estimate quantitatively the frequency of 2n-megaspores in different clones. In this connection the following recommendations may be relevant to TPS.

a. Intensification of research on the occurrence and the genetic or chemical induction of aposporic embryosac development, both at the diploid and the tetraploid level.
b. Breeding of additional diploid clones with an excellent FDR mechanism in the megasporocytes, preferably with 0% gene recombination. Through pollination with marked S. phureja such genotypes can be reproduced pseudogamically, stored as true seeds and be used either directly in 2x.4x-crosses or in breeding programmes at the diploid level.
c. Increasing the emphasis on the potential of excellent tetraploid varieties with the ability to produce 2n eggs through some efficient FDR-mechanism or rather through apospory. This enables nearly or fully identical reproduction via true seeds. If these seeds could efficiently be produced, such varieties could be grown from true seeds, possibly after one or two generations of vegetative propagation.

It might be too optimistic to expect that in the year 2000 we will have available tetraploid varieties capable of producing apomictic seed without pollination ("autonomous apomixis", Hermsen, 1980). A present, apomictic seeds can already be produced through pseudogamy, i.e. through pollinations by S. phureja. However, for the TPS technology large-scale seed production is a must, so that streamlining of true seed production, should be thoroughly investigated. In this connection some aspects are worthwhile being considered:

1. Breeding in a conventional way cytoplasmically male sterile varieties or parental lines, or transferring through genetic manipulation the nucleus of established varieties into a male-sterilizing cytoplasm. Because bumble bees avoid male sterile flowers, a type of sterility like "eclipse sterility" (Ramanna and Hermsen, 1974) originating from several S. verrucosum accessions, a. o. from PI 275258, may be useful because in spite of sterility a sufficient amount of seemingly normal pollen grains is produced. So emasculation is not needed and the insects may carry out the pollinations.

2. The ability of S. phureja to induce pseudogamic seed development might be improved to a level at which, besides hybrid seeds, a reasonable number of pseudogamic seeds per berry is obtained.

3. The separation of hybrid and pseudogamic seeds may be possible electronically, when the new dominant marker "coloured cotyledons" from S. brevidens and S. fernandezianum (Hermsen, unpubl.) will have been introduced into S. phureja. (Figure 1).

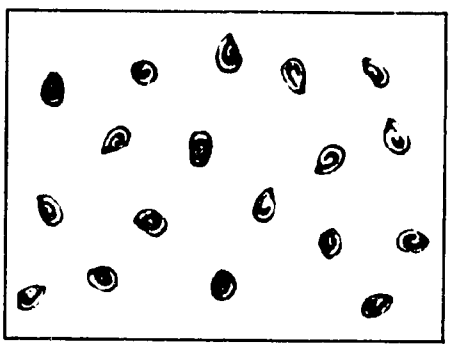

Figure 1. True seeds of S. fernandezianum showing the marker coloured cotyledons.

Selection for adapted genotypes in wild species

In CIP's breeding programme wild species are becoming increasingly important as sources of resistance. It may be expected that in the years ahead advanced clones become available which as a result of long-term breeding research are enriched with valuable genes from hardly accessible species. Examples are late blight resistance from S. bulbocastanum and S. pinnatisectum, brown rot resistance from S. jamesii and last but not least leafroll and Y virus immunity from the non-tuber bearing Chilean species S. etuberosum and S. brevidens.

During the first CIP-planning conference on the utilization of genetic resources (1974) Hermsen stressed the importance of prebreeding in wild potato species previous to hybridization with cultivated potato. Mendiburu et al. (1974) put forward a similar view. According to Hanneman (cited in Leue and Peloquin, 1980) little progress could be made in recurrent selection for field tuberization in a bulk population of S. chacoense, but considerable progress was made in bulk populations of ssp. tuberosum-haploids x S. chacoense (Leue, unpubl.) These observations may hold true also when using other important wild species like S. vernei, S. sucrense. There is still little experience in this field.

Genetic manipulation at the cellular and molecular level

a. Introduction

New developments in the field of genetic manipulation at the cellular and at the molecular level deserve the attention of plant breeders, because they may have an impact on future breeding. Some of these developments are going so rapidly and are so fascinating, that breeders have to keep themselves informed and be prepared and willing to adopt these new possibilities. On the other hand breeders should not forget that conventional breeding will remain indispensable.

Discussing briefly the aforementioned developments is like sowing seed that probably are not ready to germinate now, but certainly will be before the year 2000.

b. Generating somaclonal variation

Conventional breeding methods and also mutagenic treatments have failed to successfully improve some old, unique and widely grown varieties like Russet Burbank, Bintje, and King Edward. Selective improvement is now being tried using some unconventional approaches. One such unconventional method is the production of a large population of so-called protoclones or somaclones via culturing protoplasts and regenerating plants from them via callus, shoot and root formation successively. Shepard et al. (1980) studied more than 10,000 protoclones of Russet Burbank and found a tremendous amount of variation in horticultural traits like growth habit, maturity date, tuber characteristics, and photoperiodic requirements, but also some clones that seemed to have an improved resistance to early and late blight. According to the authors these variant protoclones have retained their phenotype through a number of vegetative generations. After eliminating grossly aberrant individuals 65 relatively normal clones were systematically investigated for variability under normal field conditions with Russet Burbank as a control (Secor and Shepard, 1981). Statistically significant variation was found in 22 of the 35 characters studied. The number of characters which differed significantly from those in the control varied from one to 17 per protoclone. Some of these characters were an improvement over the normal traits in the cultivar.

Thomas et al. (1982) obtained plants from protoplasts of shoot cultures of the cultivar Maris Bard (released in 1974). A large variation was found for all ten characters assessed. The authors obtained different plants from the same callus (=one protoplast) which indicated that the variation arose during callus growth and could not be explained on the basis of differences between cells of the leaf, from which the protoplast originated.

Bright et al. (1982) stress the importance of economical and efficient methods for obtaining somaclonal variation such that they can be applied in conjunction with conventional breeding programmes with a minimal need for skilled manpower or expensive equipment. They suggest the use of explant-derived plants instead of protoplast-derived plants, because this could reduce the time needed from four months to seven weeks. However, in preliminary experiments the plants regenerated from explant callus were found to display less variation than was observed in protoplast-derived plants.

Recently a group of researches at ITAL, Wageningen, working with the variety Bintje regenerated a large number of protoplast-derived plants which displayed a variability comparable to that found in Russet Burbank (Roest, personal communication).

It is highly relevant to investigate the origin of somaclonal variation and the possible role of the processes involved, such that variation can be enhanced or suppressed as circumstances may require. Larkin and Scowcroft (1981) in their recent review of somaclonal variation in more than ten crops, consider it improbable that some mutagen component of the media used may cause the broad spectrum of variants that occur at very high frequencies in many plant species. They mention the following hypotheses that are speculative and inadequate, but need to be investigated: gross changes in the number of chromosomes, cryptic changes associated with chromosomal re-arrangements in somatic cells, transposable elements that can directly affect neighbouring structural genes, somatic crossing over and sister chromatid exchange, and finally cryptic virus elimination influencing the reaction to fungal diseases. Larkin and Scowcroft (1981) expect that molecular genetic techniques together with sophisticated manipulation of plant cells in culture will identify and characterize specific genetic mechanisms underlying somaclonal variation.

The possible future role of somaclonal variation as an adjunct to conventional potato breeding may be welcomed, but temperance about expectations seems wise. In the year 2000 we may know whether the processes involved can be put on the track of our needs.

c. Genetic transformation

It is of interest to speculate about the possibility of introducing single genes into highly valuable genotypes with single defects, using methods of genetic manipulation at the molecular level.

Plant molecular biologists have paid considerable attention to the cloning of genes that control protein synthesis in the storage organs (the seeds) of plants. Examples are endosperm proteins of cereals and proteins of leguminous seeds. The main reason for this is, that it is relatively easy to isolate and purify the tissue specific messenger- RNA's from the developing seeds. Once a species of m-RNA is isolated, it is easy to make a complementary DNA and clone the gene in a suitable system, e.g. plasmids of bacteria.

The potato tuber is also a storage organ and it might be possible to isolate m-RNA's for the genes that code for tuber proteins. If this is true, one should expect that the genes for tuber proteins might be isolated and cloned in the future, and used in genetic transformation.

Unlike cereals, there appear to be attractive possibilities for genetic transformation in potato through the use of Ti-plasmids from Agrobacterium tumefaciens. Preliminary results from Cologne point to its feasibility in potato. Certain strains of Ti-plasmids of Agrobacterium

tumefaciens have been developed, which after inoculating the plant, directly transform its tissues. These tissues can be excised and regenerated into plants.

It might be expected that in the decades ahead genes for immunity from potato virus diseases can be identified, isolated, cloned, and transferred into varieties like Bintje, King Edward, and Russet Burbank or into parental lines.

d. Protoplast fusion or somatic hybridization

The methods of genetic manipulation are developing rapidly both at the cellular and the molecular level. Genetic manipulation at the cellular level will be a routine method in due time. Isolation of protoplasts is not a problem any more. Regeneration of plants from protoplasts has been successful in several genera. The ability of protoplasts to regenerate appears to be a heritable character, so it can be selected for. It may be expected that by the year 2000 also regeneration is a routine method in the potato in general.

For protoplast fusion good methods are available at present. Most troublesome still is the selection of heterologous fusion products out of a mixture of heterologous and homologous ones. The complementation technique, the use of albino plants and of roots of one of the parents has been applied successfully, but there is no method that is generally applicable.

So for each combination of parents the right procedure has to be developed. However, experience is growing fast and the selection problem will also be solved.

How important will somatic hybridization be by the year 2000? I expect that for practical breeding purposes there will be no need of using the fusion technique for combining genomes of Solanum species with genomes of other solanaceous genera, like Lycopersicon, Datura, Capsicum, Nicotiana, Physalis.

This is for the following reasons:

1. If species or genera cannot be hybridized in a natural way, a successful somatic hybridization may well be followed by elimination of chromosomes, by loss of cytoplasmic organelles, by aneuploidy and sterility.
2. If these abnormalities do not occur then preferential pairing of homologous chromosomes will take place and prevent gene exchange between the species or genera.
3. Two parental genotypes yield only one hybrid genotype; so there is hardly any opportunity for selection.
4. When somatic hybridization is the only way to produce a hybrid between two species, then also the first backcross can be expected to be possible only through protoplast fusion. This means that the number of chromosomes becomes too high for normal functioning of the "backcross" plants.

Within the genus Solanum and certainly within the tuber-bearing group the situation may be different. Quite a few Solanum species cannot be crossed with the cultivated potato or its dihaploids. Some species can, but only through certain bridging species. Examples are the series Bulbocastana and Etuberosa. Somatic hybridization might provide a short cut in the breeding programme, although also in this case preferential pairing may greatly restrict gene exchange between the parental species.

Somatic hybridization within a species may be useful in the following situations:

a. We want to fuse two various excellent, highly heterozygous diploids, which might directly produce tetraploids at the level of a variety. In this situation somatic hybridization is a must if either one or both diploid parents are completely sterile or when the parents are not able to produce 2n gametes through FDR.
b. We want to set up a breeding programme on the basis of monoploids (i.e. plants with 12 chromosomes in their somatic cells).

Such a breeding programme could be carried out according to the following scheme:

- Breed a variable population of diploid genotypes and select the best.
- Produce as large a population of monoploids as possible from the selected diploid clones.
- Test monoploids for presence/absence of desirable features and group them in such a way that monoploids from different groups have complementary characters.
- Fuse protoplasts of monoploids from different groups. This leads to heterozygous single cross hybrids.
- Repeat the third step with the diploid single cross hybrids.
- Fuse protoplasts of singles from different groups to obtain highly heterozygous double-cross hybrids.
- Test double-cross hybrids in the usual way.

The advantage of this approach is the feasibility of completely controlled fusion of tested genomes.

Prerequisites for practical application are a routine production of monoploids and practicability of somatic hybridization of monoploids and singles.

Then successful varieties may be obtained and vegetatively propagated.

e. Can homozygous potato lines be successfully used for breeding a uniform true seed crop?

If uniformity would be the only breeding aim, then the answer could be yes: homozygous diploids and tetraploids produce uniform single cross seed. If a good tuber yield is desirable in addition to uniformity, the answer is no, because multi-allelism is a must for optimum performance for polygenic traits in potato. Therefore the performance of single crosses, whether diploid or tetraploid, will be unsatisfactory owing to diallelism at all heterozygous loci. Double crosses will lack uniformity and have at best only 44% of the heterozygous loci in tetraallelic condition. Altogether the conclusion must be that the use of homozygous lines in breeding true seed potatoes is highly restricted. The fact that varieties obtained via monoploids are free from deleterious genes may have some meaning, because no seedlings will get lost owing to such genes.

It may be concluded that homozygous potato lines have great significance for basis research, that they may be useful for breeding only in conjunction with somatic hybridization and that for TPS-technology their significance is restricted.

f. In vitro selection for resistance

In vitro selection for resistance could be most efficient at the cellular level, e.g. in protoplast culture. However, it is required that the resistance genes are expressed in the resistant protoplasts or calli, that the effect of such genes can be detected by exposing the protoplast culture to the pathogen or a pathogen-specific toxin, and finally that resistance in vitro is correlated with resistance in the plants regenerated. Behnke (1980) obtained an increase of the level of "general" resistance to late blight in potato callus lines by treatment with culture filtrates of the fungus. Carlson (1973) treated tobacco leaf protoplasts with methionine-sulfoximine, which is related to the toxin from Pseudomonas tabaci, and found increased resistance in plants regenerated from surviving protoplasts. The number of such successful cases is low, although many experiments have been carried out. This implies that the aforementioned requirements as a rule are not fulfilled. Only when the toxins are well characterized, differential toxin responses may be found. Furthermore, it has appeared that gene expression in vitro is dependent on the composition of the medium, on the callus type, and the stage of differentiation.

Experiments have been carried out with applying the pathogen itself to the cell culture. It appeared that the cells were often killed unspecifically. Selection experiments with viruses, though successful in cultures of bacterial and animal cells, appeared hardly suitable as selective agents in vitro because they usually displayed too little pathogenecity to cause visible adverse effects on growth and development of susceptible cells or calli.

It is clear that generalizations on the potential of in vitro selection for resistance can not at all be made. There are too many basically different pathogens and mechanisms of resistance in plants. Protoplasts can exhibit only certain kinds of resistance and certainly not those that are based on histomorphological traits of plants. Lack of correlation between the reaction in vitro and the reaction of regenerated plants is still the rule.

Obviously it would be too optimistic to state that, by the year 2000, breeding of plants for resistances to pathogens would be replaced by in vitro selection for resistance to specific toxins. Although it will probably be feasible for an increasing number of diseases, it will never become a general procedure for resistance breeding. In spite of this, research should be continued in all aspects that are relevant to this new approach.

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NEW APPROACHES TO BREEDING FOR THE POTATO OF THE YEAR 2000

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It is difficult to predict precisely the characteristics, besides yield, of a successful cultivar in the year 2,000, particularly considering the diverse environments in which the potato will be grown. Thus, it is important to construct and use breeding methods that have the flexibility, efficiency, and adaptability to meet both current challenges and unexpected future problems. Further, and of utmost importance, these methods must possess the characteristics of being useable on a worldwide basis.

It appears imperative to rely most heavily on the greatest asset available to potato breeders - the germplasm in the many cultivated and wild relatives of the commercially grown potato. This germplasm not only possesses all the genetic variability for specific desirable traits that we need, but equally important it provides abundant genetic diversity for the breeder to use in obtaining high yields by developing cultivars with maximum heterozygosity to capitalize on the importance of intra and interlocus interactions.

We are lucky to have this immense storehouse of genetic diversity and even luckier that it can be incorporated into cultivars with ease. It is usually possible to obtain hybrids through sexual crosses, the hybrids are vigorous, the chromosomes pair normally (due to lack of extensive chromosome differentiation in the taxons), crossing-over occurs normally, and fertility is good. Thus, we can either incorporate small segments of the chromosomes of related species into cultivars to obtain specific characters or many segments to either contribute to quantitative characters or to increase genetic diversity.

It is important to point out that no other economic plant approaches potato in the genetic diversity available in related species and the facility with which this germplasm can be incorporated into cultivars.

Breeding methods can be conveniently divided into three types:

1) Conventional - which makes use of the normal sexual cycle involving n gametes and 2n sporophytes;
2) Modified conventional - characterized by employing alterations of the normal sexual cycle, particularly n sporophytes (haploids) and 2n gametes; and
3) Non-conventional - these include approaches based on cell culture and molecular methods, and they usually do not involve the sexual cycle.

This portion of the paper will consider modified conventional approaches. However, before discussing these, a few comments should be made in relation to conventional breeding. One, the advances in the past have been made with this method, and it is most likely that it will continue to be very important in the future. Second, new advances in cell culture, molecular biology, and cytogenetics, which are related to breeding, will not by themselves increase the food supply unless there are strong cultivar breeding programs. The latter must exist to make use of new findings in other disciplines to develop better cultivars (Peloquin, 1981).

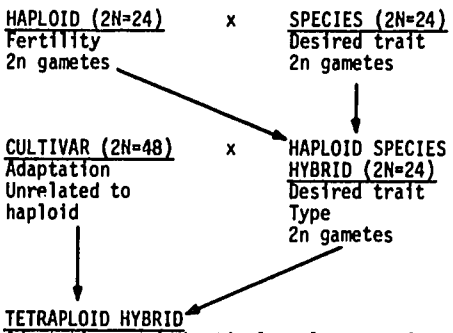
The discussion of modified conventional breeding schemes will emphasize the use of species, haploids, and 2n gametes. The overall breeding strategy involves three main components; the species provide the source of genetic diversity, haploids of Tuberosum and Andigena provide a method to capture the genetic diversity, and 2n gametes are an effective and efficient way to transmit genetic diversity. Genetic diversity is used here to include both valuable qualitative and quantitative traits, and the allelic variation necessary for maximum heterozygosity.

Five breeding schemes are presented. They are given in order of their chance of success in time based on current research results and leads. All schemes are applicable to both breeding for tubers and true potato seed (TPS). The five schemes have distinctive features and thus justify being considered separately. However, it should be recognized that some have common ingredients, and further that the specifics in regard to the materials, selection factors, and reproductive processes are somewhat arbitrary, since it would have been impossible to include all possible alternatives. The basic ingredients of each scheme will be discussed in relation to current research results, and indicate direction of future research to either improve or initiate a particular scheme.

Breeding Scheme 1 is the Unilateral Sexual Polyploidization method (Mendiburu, Peloquin, and Mok, 1974). It involves obtaining 4x progeny from 4x x 2x FDR (First Division Restitution), by a mechanism such as parallel spindles, (Mok and Peloquin, 1975a), which transmits about 80% of the heterozygosity of the 2x parent to the offspring). Haploids (2n=2x=24) of cultivars or advanced selections (2n=4x=48) are obtained and selected for fertility and 2n gametes. Introductions of cultivated or wild 24 chromosome species are selected for 2n gamete formation, and desired traits, such as disease resistance. Hybrids (2n=2x=24) between haploids and species are obtained and selected for the desired traits, type (good vines, flowering, and tubers) and 2n gametes. These selected 2x hybrids are

crossed to cultivars which possess good adaptation and are unrelated to the haploids involved in the 2x hybrid. The 4x hybrids from the 4x-2x crosses obtain their adaptation and horticultural type from the cultivar, and the desired traits and allelic variation from the haploid-species hybrid. This scheme has wide application, since one can use the best locally adapted cultivars from any area in crosses with the most heterotic 2x hybrids.

Breeding Scheme 1



This scheme has and is being used to obtain high yielding 4x hybrids (DeJong et al., 1981; Hanneman and Peloquin, 1969; Mendiburu and Peloquin, 1971; and Mok and Peloquin, 1975). It is also a good method for production of TPS due to the excellent seedling vigor, and the yield and uniformity of 4x hybrids. These hybrids have about twice the tuber yields of progeny from open-pollinated seed and are significantly more uniform in vegetative vigor and tuber yield.

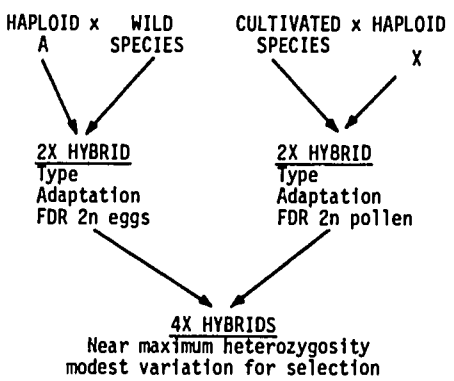
This method can be improved significantly by improving the tuber type of the 2x hybrids. The best 2x hybrids used in the past have deep eyes and raised internodes. Recently, 2x hybrids with FDR and good tuber type have been obtained by intermating relatively unrelated 2x hybrids that produce 2n pollen by FDR (Okwuagwu, 1981). It would also be possible to obtain similar 2x hybrids by intermating between new haploids and Phureja clones selected for good tuber type and FDR or to select within Phureja.

Recently, a new meiotic variant was discovered which adds to the effectiveness of the 4x-2x and 2x-2x breeding schemes. It is characterized by lack of crossing-over at meiosis, thus only univalents are present at metaphase I. Ordinarily, this behaviour would lead to complete male sterility. However, when the synaptic variant is combined with the parallel spindles, mutant, fertile 2n pollen is produced. The genetic significance of this combination of meiotic variants is that it makes possible the incorporation of the intact genotype of the parent into all the gametes. Thus, an exceptional opportunity is possible- transmitting 100% of the heterozygosity and epistasis of the parent to the offspring (Okwuagwu and Peloquin, 1981).

Another recent finding can also contribute to the efficiency of the 4x-2x and 2x-2x breeding schemes. This is the discovery of the topiary (tp) mutant in S. infundibuliforme (Leue and Peloquin, 1982). This mutant is pleiotropic in that it affects branching, stolon length, time of tuber initiation, and second growth on tubers. The majority of the wild species do not tuberize in the field in temperate climates, so it is not possible to estimate variation within genotypes from a species for yield, which must certainly exist. By crossing tp mutants with other species and observing tuberization of the topiary types in the F_2, one can make selections for tuber yield. These selections can then be crossed to haploids to obtain the most productive hybrids.

Breeding Scheme 2 involves the synthesis of 4x hybrids from 2x-2x crosses, Bilateral Sexual Polyploidization (Mendiburu and Peloquin, 1977). It provides a longer range breeding method with great potential. One needs to develop superior, unrelated 2x hybrids selected for type, adaptation, 2n gametes by FDR, and other desired characteristics. This type of hybrid involving Tuberosum haploids and Phureja is available. More recently, hybrids, with adaptation and 2n gametes, have been obtained from crosses between haploids and the wild 24-chromosome species, S. chacoense (Leue and Peloquin, 1981). This is an important step, since this species from Argentina is a source of genetic diversity, vegetative vigor, profuse flowering, high fertility, long tuber dormancy, and both disease and insect resistance. A further advantage is that S. chacoense, unlike Phureja, does not possess dominant genes which interact with Tuberosum cytoplasm to give male sterility. Thus, it can be used to cross onto male sterile, female fertile haploids to obtain male fertile hybrids. Consequently, the majority of haploids which are male sterile can be used to develop 2x hybrids.

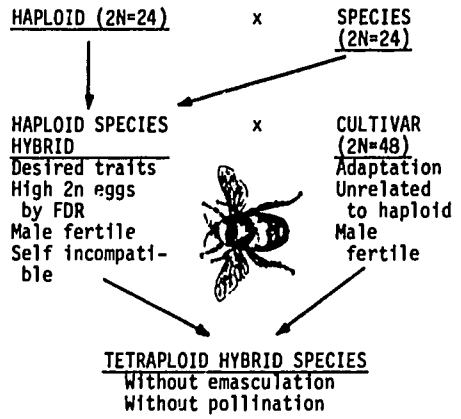
Breeding Scheme 2



S. chacoense does not tuberize under long-day conditions, has very long stolons, and selection for tuberization has not proved affective. However, some F_1 hybrids between S. chacoense and particular haploids have short stolons, and their tuber yields can be two to four times that of the haploids. The best F_1 hybrids have yields that are similar to cultivars. Another surprising and important result with the haploid S. chacoense F_1 hybrids, was the large variation in maturity. Some clones were as early as the earliest cultivar while others were later than any of the cultivars (Leue, 1982).

Breeding Scheme 3 is a method of obtaining 4x progeny from (2x x 4x) crosses. It is essentially the reciprocal of Scheme 1, and it has all the advantages of the latter scheme. But it has one additional asset in relation to TPS production in that it provides an economical method to produce hybrid TPS. It is more economical, since hybrid TPS could be produced without either emasculation or pollination. Instead the bumble bees would do the pollinating, and the self-incompatibility system of the 2x hybrid would prevent self-seed production.

Breeding Scheme 3



Observations indicate that bumble bees rarely visit male sterile flowers. Thus, one cannot use the simple scheme of having the bees take pollen from a male fertile clone and transfer it to a male sterile clone to obtain hybrid TPS. Scheme 3 overcomes this problem by having the seed parent be male fertile, but self-incompatible.

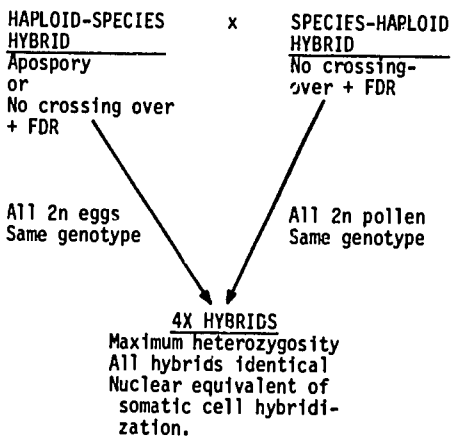
The requirements of this scheme are to have haploid-species hybrids with the following characteristics; 1) the desired traits, 2) very high frequencies of 2n eggs formed by FDR, 3) male fertility, and 4) self incompatibility. The 4x clone, which should be unrelated to the haploid of the 2x clones must be highly adapted to the area the hybrid TPS would be used and have good male fertility. The 2x and 4x clones would be alternatively spaced in an isolated crossing block. The bees would be attracted to both 2x and 4x clones, since they are both male fertile, and the 4x hybrid seed would be produced on 2x clone.

Two problems need to be solved to make extensive use of this method. One, 2x hybrids must be identified that produce high frequencies of 2n eggs by FDR. Currently, clones are available with either low frequencies of 2n eggs by FDR or high frequencies of 2n eggs (resulting in 50-100 seeds/fruit in 2x x 4x crosses), but the mode of 2n egg formation has not been identified (Leue, 1982). Four approaches are being used to determine the mode of 2n egg formation; direct cytology, genetic analysis by half-tetrad analyses with electrophoretic markers, pollen stainability distributions of 4x progeny from 2x x 4x crosses, and the yield and uniformity of 4x progeny from 2x x 4x crosses, (Iwanaga and Peloquin, 1980). The second problem involves the type of planting plan of the 2x and 4x clones that will result in the bees making the maximum number of pollinations of the 2x clones with pollen from the 4x clone.

The efficiency of Scheme 3 in relation to hybrid TPS production behooves us to spend significant effort in solving these problems. The economic benefits of positive results would dwarf the modest research investments needed to solve the problems.

Breeding Scheme 4 is a longer range approach in which identical 4x hybrids with maximum heterozygosity are produced from 2x - 2x crosses. It is essentially an idealized version of Scheme 2 with components of Hermsen's Utopian Scheme (Hermsen, 1980). Two types of 2x hybrids are needed to derive maximum benefits from this scheme. One 2x hybrid must produce highly heterozygous male gametes which are all of the same genotype. A meiotic system involving no crossing-over followed by FDR accomplishes this goal. The other 2x hybrid must produce a high frequency of 2n eggs, all of the same genotype and highly heterozygous. This would occur either through apospory, the development of the female gametophyte from a somatic cell, or via a meiotic sequence, with no crossing-over followed by FDR (Iwanaga and Peloquin, 1979). In both types of 2x hybrids all the 2n pollen and all the 2n eggs would have the same genotypes as their respective sporophytes.

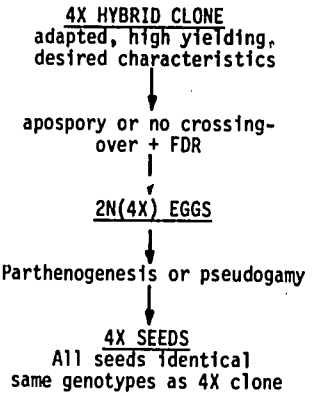
Breeding Scheme 4



The male side of the scheme is solved. The combination of the meiotic variants sy3 (all univalents at the first division of meiosis) and ps (parallel spindles) at the second meiotic division results in 100% of the genotype of the parents being transmitted to all the male gametes. The female remains a problem for further research. Currently, a systematic method of forming 2n eggs by either no crossing-over followed by FDR or apospory has not been identified. But one should be reasonably optimistic that even modest research efforts would be very fruitful. It is important to point out that Scheme 4 is the nuclear equivalent of somatic cell hybridization. Further, that this scheme probably could be accomplished in less time and for a fraction of the research investment needed to obtain similar results with cell culture.

Breeding Scheme 5 is in some aspects less a breeding scheme than it is an attempt to exploit the potential of apomixis. The concept is to develop an asexual system in which all the 4x seeds obtained from a highly desirable clone, are identical and have the same genotype as the 4x hybrid clone. In order for this to occur substitutes for both meiosis and fertilization are needed. The substitute for meiosis can be either apospory or no crossing-over plus FDR to give 4x eggs, and in place of fertilization either parthenogenesis or pseudogamy, depending on whether pollination alone or pollination and fertilization of the central cell are necessary for endosperm development.

Breeding Scheme 5



The induction of aposporous apomictic seed development has unusual potential for both potato research and production. For example, complete genetic uniformity in seedling families could be obtained for growing the crop from TPS. Two recent preliminary results suggest this scheme is worthy of research effort. One, a clone was identified in which more than 5% of ovules had enlarged nucellar cells in which the nucleus divided without cytokinesis (Iwanaga and Peloquin, 1982). These resembled multinucleated cells found to give rise to female gametophytes in other apomictic species (Gustafsson, 1947). Second, Irikura (1981) reported induction of apomictic seed formation by spraying emasculated flowers with various concentrations of 2,4-D. Two 4x cultivars and three 2x clones gave rise to apomictic offspring with the sporophytic chromosome number following treatment. Interestingly, the seedlings were phenotypically similar to their parents. These two clues plus the great potential of aposporous apomixis justify intensive research to explore Scheme 5.

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INTEGRATED PEST CONTROL: NEW APPROACHES TO THE PRIORITY COMPONENTS

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Introduction

Since the end of World War II, chemical pesticides have been the dominant weapon against pests in most parts of the world. However, due to the limitations of this method, in the last two decades an increasing attention has been given to Integrated Pest Management (IPM) (also known as Integrated Pest Control or Integrated Crop Protection).

IPM started in entomology but now it is an interdisciplinary system that considers all the pests of a crop production system; namely insects, pathogens, nematodes, and weeds and the various factors that affect their incidence. The great interest and general acceptance of IPM is the result of the inadequacies and ever increasing costs of conventional crop protection programs, the toxicological hazards of pesticides to people and animals, the persistence and intensification of pest damage to agricultural production systems in spite of the improvements in crop protection technology, the increasing pressure on crop protection problems due to the adoption of the "green revolution" technology, and the general concern for the quality of the environment.

IPM is accomplished by the use of multiple tactics in an ecologically compatible manner to maintain pest damage at profitable levels, avoiding or minimizing undesirable effects on humans, animals, plants and the environment. It is important to emphasize that IPM is not considered a goal per se; it must be viewed as the crop protection component in the crop production process.

Limitations of chemical control

In the last 3 decades use of pesticides for control of insects, and nematodes and other pests has greatly contributed to the increasing production of food and fibers. Despite the gains obtained from using chemical pesticides, plant protection specialists (particularly entomologists) have come to realize that the overdependence (in some cases complete dependence) on chemical control is loaded with serious handicaps.

Prices of synthetic organic pesticides, which are dependent upon petroleum in their production, have increased significantly in recent years. There are many examples where heavy use of pesticides raises production costs to the point where the crop can no longer be grown profitably.

Resistance. One of the most important problems has been development of resistance by pests to chemical pesticides. Significant groups of pests no longer can be controlled economically with chemicals because they have developed certain levels of genetic resistance. The rate of discovery of new insecticides to counteract the problem of resistance is not keeping pace with the emergence of new strains of resistant insect pests. The Colorado potato beetle, for example, has developed resistance to organochlorine, organophosphorus and carbamate insecticides in many parts of the United States (Harris and Svec, 1981). The green peach aphid, a very important vector of potato viruses, is now resistant to most insecticides registered for potatoes (Rodcliffe et al., 1979).

Destruction of beneficial organisms. Pesticides drastically affect beneficial insect populations (parasitoids and predators). As a result, 2 kinds of phenomena occur:

The population of the target species may quickly recover from the pesticide action and rise to a new and higher level. This is known as "pest resurgence." Shelton et al. (1981) has recently reported the rapid resurgence of the potato tuberworm after insecticide destruction of its natural enemies.

More important is the fact that following pesticide treatments other non-target insects may increase to damaging levels (secondary pest outbreaks or "new pests") and these new pests may become now more important than the primary ones. In the coastal area of Peru potato leaf miners became severe pests as result of heavy insecticide applications against Scrobipalpula absoluta and now most insecticide sprays are directed against the new induced pest.

Environmental contamination. Because of the problems farmers are forced to use increasing quantities of toxic chemiclas resulting in higher costs and new problems: The pesticide may remain in or on the crop products creating residue problems. The pesticide may remain in the soil, drift to other nearby areas, flow into streams and drainages and thereby create hazard to man, domestic animals, wildlife, pollinators, and other beneficial forms, causing what is known as environmental contamination and disruption of the ecosystem. Just as important is the increasing insecticidal poisoning of agricultural workers in developing countries.

In conclusion, for most of the farmers, particularly those small farmers from developing countries, it will be very difficult to rely heavily on pesticides to solve their insect, disease, and weed problems in the near future.

Basic concepts and characteristics of IPM

Agro-ecosystems. A basic concept of the ecological understanding of field crops, cropping systems and the development of pests, is that of the ecosystem, or more properly the agro-ecosystem. An artificial ecosystem is characterized by the dominance of a plant species (the crop plant) as a result of man's action. Man plants the crop and tries to keep it as a dominant species by protecting it against other plant species (weeds) and organisms such as insects, nematodes and other pathogens. In most cases, as a result of man's selecting activity, crops acquire new qualities quite distinct from the wild forms. These include changes in morphology, chemical content, phenology, and physiology. In becoming more valuable to man, crop plants may also become equally and sometimes even more acceptable to phytophagous organisms.

On the other hand, an agro-ecosystem represents the destruction of the historically formed natural ecosystem which had its own interspecific relations and mechanisms for the regulation of the numbers of their components. The agro-ecosystem creates new conditions such as the reduced genetic variability of the crop plant population, the uniformity of development stages of the plant over large areas, irrigation, fertilization, and other practices. Pest species can adaptively vary and become increasingly harmonized with the new conditions and this includes development of resistance to pesticides.

Agricultural ecosystems are less complex than natural ecosystems, a condition that makes them less stable. In spite of being less complex, the agro-ecosystem shows all kinds of interactions both injurious and beneficial among the organisms present in the field and the physical and chemical factors of the environment. So that any change in one factor usually impacts on other factors.

There is an additional component equally important, that is the socioeconomic characteristic of the agro-ecosystem, which will determine what can be done and what can not be done in the system.

The concept of equilibrium position of pests. The average population density level is the equilibrium position of the pest, and it differs in such a way that some species become more abundant than others for the given condition of a particular ecosystem. In this way, without man's intervention, just as a result of the natural forces in a given agro-ecosystem, some species, generally very few, are going to be prevalent. They may be serious persistent pests known as "key pests." Other species may become pests occasionally (they are "occasional pests") and finally some organisms will normally be at low, non-injurious population levels; they are only "potential pests."

Among all the factors present in the ecosystem a few may be key factors; they are responsible for the population level of the pest species; may be agronomic practices, presence or absence of natural enemies, and high or low resistance or tolerance level of the plant crop. Correspondingly, any changes in these key factors may also change the pest status of the organism although this may not be an immediate effect.

The concept of economic threshold. The concepts of key and occasional pests as well as non-injurious organisms already mentioned is related to the idea of economic threshold and this marks a clear difference in the old and new concepts of a pest. In the past, more attention was given to the presence of a reputedly injurious organism than to the real effect of the organism in reducing yields.

The presence of sub-economic levels of injurious organisms, particularly insects, not only does not affect yields but allows the occurrence and maintenance of beneficial organisms, parasitoids and predators. The actions of these organisms usually avoid the occurrence of pests outbreaks. So, eradication can not be considered any more the general goal of crop protection except for special circumstances.

Limitations of unilateral forms of control. Except for a few cases of successful biological control on specific insect pests, complete reliance on a single component control practice for crop protection has seldom succeeded over a long term. This is largely due to the fact that any modification of the agro-ecosystem may affect the balance of the other components. If we make the environment unfavorable to a particular pest, we may make it favorable for some other organisms.

Natural control agents as a base of IPM. Numerical growth of any pest population is regulated by limited resources such as food, space and shelter; by periodic inclement weather such as heat, cold, wind, drought and rain; by competition within the species or with other species utilizing similar resources; and by natural enemies.

Natural enemies (parasitoids, predators and pest-pathogens) are particularly significant for the control of many species of insects and mites. In tropical and subtropical areas it is considered that

the biotic elements which developed as population regulation mechanisms are dominant factors.

The task of an IPM specialist is to conserve and protect the natural biological control agents and complement their effect with other forms of control including the selective use of chemicals.

Guidelines for developing IPM programs

Bottrell (1979) in a general review of IPM refers to the guidelines that are common for any IPM program. Some of his ideas have been taken as a base for the following discussion.

Analyze the "pest" status of each of the reputedly injurious organisms. We already defined a key pest, it is the focal point of analysis and management and dominates control practices because in the absence of deliberate control efforts by man, the pest persists and causes severe economic injury.

In the case of potatoes, 7 bacterial, 44 fungal, 24 viral, 2 micoplasmic diseases and 38 species of nematodes that attack potatoes are described (Hooker, 1981). A few are key diseases or pests over very large areas such as the late blight, the bacterial wilt, the cyst and root-knot nematodes. Others may be key pests in more restricted areas.

As far as insects are concerned, there are dozens of species that attack potatoes. Aphids and the potato tuber worm are worldwide in distribution. Other species, such as the Andean potato weevil or the Colorado potato beetle are key pests in their respective areas of distribution. Insects such as Chrysomelids may become key pests in the humid tropics.

In addition to the determination of the key pests it is required to identify the species that hold the status of "occasional pests" and "potential pests" because these species are usually under adequate biological or environmental control and this condition should be preserved.

Establish economic thresholds for the real pests. Establishing economic thresholds is a very difficult task. Ideally it should be based on accurate assessment of potential damage and economic costs of control. In practice, economic injury thresholds can be determined initially, in a tentative way, based on empirical evidence by deduction from experiences in the past. These levels should be reviewed and re-adjusted with new observations and specially designed experiments.

Attempts to establish economic thresholds for potato insect pests such as green peach aphid and potato leafhoppers are very recent (Radcliffe et al., 1979) and refers to the conditions of mid-northern United States. A great deal of work remains to be done in developing countries.

Develop reliable monitoring techniques. Measurement of pest populations within the fields is essential to any IPM program. Pest populations are dynamic due to the constant changes of the environmental factors that affect their growth and decline (i.e., weather, crop growth, natural enemies, etc.). In order to initiate any rational control program it is required to determine first the presence and abundance of both pest and beneficial species.

Methods of assessing pest and beneficial population densities must be rapid, practical and accurate. The information obtained is used for pest management decisions, including the timing of pesticide applications. In the case of potatoes, most of the efforts are restricted to establish prediction mechanisms of epidemic development of late blight for temperate regions (Fry and Bruck, 1979). This information would permit a better timing of fungicide sprays against this disease.

Devise schemes for lowering equilibrium position of key pests. Reducing the key pest's equilibrium position, in a permanent way, to a level lower than the economic threshold is a primary objective of IPM. This may be accomplished through the manipulation of the environment using the following techniques, singly or in combination.

Utilization of pest-resistant or pest-tolerant cultivars. A resistant cultivar is a major component of any IPM system. It is very difficult, if not impossible, to implement IPM programs based on susceptible cultivars. In general, resistance can be used in two ways (Maxwell and Adkisson, 1981).

- As principal control method using cultivars with high level of resistance. A few insect pests and many plant diseases have been controlled with resistant varieties as the principal control method. The most attractive feature of this method is that virtually no skill in pest control or cash investment is required of the grower.
- As a major component in integrated pest management programs. Resistant varieties are highly compatible with other tactics such as biological, cultural and chemical control. The major advantage of using a resistant variety is to slow pest population growth. Varieties with only moderate levels of resistance or tolerance allow a few pests to remain on the crop at subeconomic levels and serve as a food for the natural enemies, including those species that prey upon pests to which the variety is not resistant.

Resistant varieties require less pesticide protection not only in terms of frequency of treatments, but also in lower dosages. They lessen the expense of producing the crop, conserve insect natural enemies, preserve environmental quality, and slow the rate of development of insecticide resistant pest strains (Maxwell and Adkinsson, 1981).

In the case of potatoes, I must say it is fortunate that a major portion of CIP's research is to utilize the genetic variability present in the World Potato Collection to incorporate resistance to pests into potato varieties. Reviews of the successful findings and perspectives are found in the reports of the planning conferences on the control of bacterial, fungal, and viral diseases and nematodes.

Introduction and protection of natural enemies (parasitoids, predators and pathogens). The introduction of a crop may be followed by the introduction of pests. When this occurs the pest usually develops rapidly in absence of its natural enemies. In such cases, it becomes necessary to re-establish the regulating mechanisms by introducing the natural enemies from their native areas.

The potential value of natural enemies of potato pests is largely unknown. A complete and careful analysis of mortality factors existing in the potato agroecosystem of the Andean region is needed. This should be more than a mere cataloging of parasitoids, predators and pest pathogens. It should be an analysis of how, when and where they are effective and ineffective in regulating pest species. This can be followed by the study of ways that these natural mortality factors can be augmented and supplemented, or introduced to other areas.

In the particular case of potato nematodes, an important step forward has been given with the discovery at CIP of an efficient form of the fungus Paecilomyces lilacinus parasitic on root-knot and cyst nematodes.

Modification of the pest environment. This is carried out in such a way as to make it unfavorable for breeding, feeding and sheltering of the pest, to increase the effectiveness of its biological control agents, or otherwise, to render it harmless. This is related to the agronomic practices, planting dates, crop rotation, soil tillage, destruction of crop harvest residues, sanitation, clean seed, cropping systems, etc.

Certified seed. The availability of disease-free seed is very important for any crop production, but when the crop is vegetatively propagated, as is the case of potatoes, the use of certified seed is considered basic. Potato seed certification in developing countries, however, faces many difficulties and with a few exceptions it has not been successful. A partial alternative to this problem is development of a practical technology to use true seed in propagation of potatoes taking advantage of the role of true seed as a natural filter for most pests (Page and Bryan, 1979).

Cropping systems. Biological stability, including regulation of pest populations, is affected by diversity of cropping systems. It is a fact that severe infestations seldom occur in highly diversified, mixed farming areas. In the case of potatoes, the tuber has been cultivated as a major food for a thousand years in the Andes where the small farmer grows a mixture of clones and intercrops potatoes with other plant species. Recent research has demonstrated, particularly in tropical areas, the efficacy of mixed cropping and intercropping in reducing pest and disease damage.

It is time to study in detail the various effects of mixtures of potato clones, mixed cropping and intercropping as forms of integrated potato production systems in developing countries.

Cultural practices. Agronomic practices offer many possibilities to reduce the incidence of pests and deserve more detailed studies. Some cultural methods hardly accepted in temperate regions may play an important role in developing countries. In the Andean region, long rotations have been used successfully against cyst nematodes and fungi since ancient times. Adequate "hilling" giving good coverage of tubers with soil provides tuber protection against late blight, tuberworm and, to certain extent, to the Andean weevil. Many other examples can be given of agronomic practices and sanitation procedures of importance in controlling potato pests.

The introduction of new agricultural practices, however, must be cautious, because an inadequate change in the agro-

ecosystem may have disastrous results. Thurston (1981) refers to a case in Colombia, in the late 50's, when the use of cut seed pieces was introduced, a common practice in temperate regions, as an alternative to the native custom of planting whole tubers. When cut seed was used the first time it all rotted in the soil due to fungi. When this problem was solved by using fungicide seed treatments the bacterial wilt became a serious problem. Only when they went back to using whole seed tubers did this problem disappear.

Review of direct and side effects of unilateral forms of control. Study of unilateral forms of control should be done in the context of the associated environment and the population dynamics of the pest species. In the case of chemical control, for example, this includes not only the measurement of the effects on the target species but also the effects of pesticides on natural enemies and other beneficial organisms. The additional information permits the IPM specialist to incorporate the various tactics of control into integrated systems.

During emergency situations, seek remedial measures that cause minimum ecological disruption. When, despite the efforts to avoid it, the key pest flares up or the secondary pests are out of control, remedial measures must be taken; pesticides may be the only resource and their use should be as selective as possible. Selection of the pesticide, dosage, timing, formulation and degree of coverage must be carefully coordinated to avoid undesirable effects.

In summary, in order to implement IPM programs in potatoes, particularly under tropical and subtropical conditions there is need of further research in several components. This work requires the contribution of all scientists in potato research, because plant protection problems are not independent from the other factors of the potato production system.

High levels of resistance are not necessary for a potato variety to have value in an integrated control program. Regulation factors of potato pest populations need to be assessed. Reliance on chemical protection should not be overemphasized and the potato should be studied as part of cropping systems for small farmers.

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LIMITING FACTORS TO THE EXTENSION OF THE POTATO INTO NON-TRADITIONAL CLIMATES

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Should the potato be introduced into non-traditional climates?

It is a fact that at the present time the potato has the potential to produce, within convenient climatic and soil conditions, high yields in energy and protein per unit soil surface per day of growing season. From the nutritional point of view, the potato is a balanced food. Approximately one half hectare is in many cases sufficient to satisfy the food needs of an average family; furthermore, the potato could be an ideal addition to food crops already grown in a region. "Non-traditional" means that the potato for various reasons has not become a well known crop in such a region. This however, does not mean that the potato is not known as a food; in many countries belonging to the non-traditional climates, i.e., the non-potato growing regions, the crop is known as a luxury food -- a vegetable -- but not as a common food. Why should the potato be brought into these non-traditional climates? Certainly there is an increasing demand. However, there are factors in favor of such an extension, but also some which need a cautious evaluation. Favorable factors include:

- the yield potential for energy, protein, and nutritious food quality;
- the potential of the potato to contribute to an increase in food production within a short time, an essential aspect in regions with a rapidly growing population;
- the potential to grow the potato for self-subsistence in a relatively short growing period;
- the chance to make the potato a relatively cheap food.

It is our goal to identify factors which may limit the extension of the potato either as a seasonal main crop or in an intercropping system. Factors which must be evaluated very carefully are socio-economic as well as physical-technological. We will also recommend courses of action to deal with some of the limiting factors to the introduction of potatoes into non-traditional climates.

Definition of the term "non-traditional climate"

As we already mentioned the term "non-traditional climate" does not necessarily imply that the potato as a food is not accepted in such a region; it only means that the potato is not grown to any great extent. Looking at the growing conditions, the term "non-traditional climate" characterizes mainly the hot climates of the tropical region in altitudes up to 1000 m, i.e., regions with a day length of approximately 12 h, minimum night temperatures of 19-20°C, and maximum day temperatures as high as 40°C (Accatino, 1981). Seasons of heavy rainfall may alternate with dry ones. Non-traditional regions could have a continuous or discontinuous pattern of rainfall (1500-5000 mm); they also could be semi-arid with 400 mm of precipitation or less. Other factors characterizing non-traditional climates may be soils with a pH ranging from 4.3 to 5 and aluminum toxicity in hot humid tropics; salinity could be limiting in arid regions. Such conditions refer to non-traditional regions or parts of them e.g., in the Philippines, Indonesia, Thailand, Sri Lanka, India, Pakistan, the Middle East, Northern Africa, hot and dry regions in Africa, Central America, Colombia, Venezuela, Ecuador, Brazil, and Peru. FAO published a series of reports on the agroecological zones. It becomes evident that in most of the above-mentioned regions, the traditional potato growing areas, also referred to as "potential potato growing areas", are very small. According to the mentioned FAO-studies, a traditional climate in the tropics or sub-tropics for potato production is described as:

- cool tropics with 10-15°C daily mean-temperature during the growing season;
- warm/moderate cool sub-tropics (15-20°C daily mean temperature) with summer rainfall;
- moderate cool sub-tropics (15-20°C daily mean temperature) with summer rainfall;
- cool sub-tropics with summer rainfall and 10-15°C daily mean temperature;
- cool sub-tropics with winter rainfall and 10-20°C daily mean temperature.

Socio-economic questions

The knowledge of the potato is certainly widespread in the world. Decades ago European nations in particular contributed to this fact. More recently CIP with its worldwide network and in cooperation with National Programs took the opportunity to play an active role. Looking at the success of these common efforts, however, one must conclude that even in traditional climates of developing countries it is extremely difficult to extend the potato crop and to raise and stabilize the yields -- this although potato scientists are convinced that there is a tremendous gap between the theoretical yield potential and the average as well as the experimental yields. When we are analyzing the factors for low potato yields in developing countries belonging to traditional climates, we always compare the stand of

the potato crop with the stand of other adapted crops, such as corn, wheat, faba beans, and rice. From this comparison we often have to draw the conclusion that the potato is a very demanding crop with many more risks than other ones; farmers have many more difficulties in managing potato cultivation, even if they are experienced. Why is this so? Not only are there environmental or genetic factors which are of much importance. Also of importance are socio-economic factors, and they may become crucial. The following socio-economic questions should be given careful consideration before a decision is made to extend the potato into a new region:

- is it necessary and wise to change the daily diet of the population?
- has the diet in the past been so unhealthy, or is it only a problem of raising the quantity of food? Is hunger and malnutrition only the problem for the poor, landless population which has no basis for a subsistence production? In many cases this and not the need for a change in the diet is the true reason for malnutrition.
- does the potato have a chance to be accepted as new food in the non-traditional area, this without pressure of food shortage and starvation? What could be done to catalyze the first promising indications?
- is the potato the crop which could improve the food situation in the region much better than another crop, already known and grown?
- would it be of advantage not just to look at the potato alone, but also at the improvement of complementary local crops, such as peas, beans, soybeans, faba beans, etc.?
- would it be possible to improve, for example, the yielding potential or cultivation techniques for such traditional crops much more easily and rapidly than to overcome the barriers to the introduction of the potato?
- who will need the potato? Does the potato have a chance to become a cheap food available also for the poor population, since not everyone in large town-agglomerations can grow potatoes for self-subsistence? This always should be considered as a factor of high priority in regard to the extension into non-traditional climates.
- does the small holder have a fair chance to sell his surplus potatoes for an acceptable price on the market?
- what can be done on the consumer and/or market level so that newly developed, higher yielding, resistant varieties with good shape and taste will be accepted? Many of us could tell stories in this respect from the northern hemisphere.

Recommendations on approaches to socio-economic limits

We recognize it is not easy for all of us who are associated with the potato crop to appreciate that limits of a socio-economic character may be very important with regard to an extension of this crop into non-traditional climates. Food price policy should be designed to provide significant stimulation of production by smaller holders. At the same time, however, any exorbitant increase of prices to the poor purchaser should be avoided. Therefore, "the urgency to move forward in potato research and to avoid the mundane which often characterized research of the last several decades" (Page, 1981) likewise necessitates the initiation or acceleration of the evaluation of the above mentioned socio-economic factors. The aim should be: a) to prepare a smooth introduction of the potato as soon as it is ready from the technological point of view as a real help for those who need help in order to overcome hunger, or alternatively, b) to state clearly that the potato in the given situation is not providing the optimal solution. This is not to criticize the potato. Probably we all know that introduction of a new food or a new crop to grow requires about one generation's time unless there is a situation of food shortage. Even in times of food shortage it might be more efficient to concentrate all efforts on the increase of food production with well known, adapted, and accepted crops in non-traditional potato climates.

The International Potato Center has the obligation at all times to examine and to adapt the priority of each thrust. It is necessary to concentrate efforts on short-, middle- and long-term goals. The extension of the potato to non-traditional climates belongs to the middle- and long-term goals, since the chance to be successful depends not only on potato research but to a considerable extent on factors which are beyond the influence of potato scientists. This, however, does mean that common and increasing efforts have to be undertaken in order to take the opportunity to introduce the potato crop into new regions as soon as a favorable situation is present. All partners in this challenging endeavor --the CIP breeders, pathologists, entomologists, seed production specialists, and agronomists, and especially the socio-economists together with their colleagues of the Regions and the National Programs-- have to be ready at the same and at the correct time. This is in our opinion an essential aspect in the whole strategy. It is our assumption that all people involved in this process will be well prepared and will possess adequate technique, i.e. that they will be experienced to conduct on-farm research and research on the consumer, as well as at the market-level. CIP scientists are able to catalyze many actions; we appreciate very much that they took the opportunity to become active and successful. The real break-through, however, has to come from a special engagement of national experts.

This type of research work aims for early identification of important economic and social constraints. It must be carried out early and requires the work of interdisciplinary teams. The socio-economic constraints, in whatever form they may exist in a given area, should be analyzed before major efforts on the production level are started in that area. We know, of course, that political constraints too may have influences which cannot be controlled. It is clear, however, that socio-economic research has a key function and that it has a tremendous chance in the different non-traditional climates to improve the efficiency of scientific research in relation to breeding for yield, resistances, and other agronomic characteristics. This is a real challenge! (We say this as scientists involved in research aimed at overcoming limiting factors on the production level.) We would not limit the composition of such teams to scientists (anthropologists, economists, agronomists, seed production specialists, plant protection specialists, etc.) affiliated in one or the other way with CIP or National Potato Programs. The potato in non-traditional climates has to be integrated into established patterns of crop production (for instance, as one of several crops grown per year). Therefore, to create an integrated production system it will be of special importance to cooperate with experts having experience with other crops, or even with animal husbandry, e.g. with national experts or experts from other international CGIAR-centers. This may open possibilities for intercropping and for the establishment of a crop rotation, thus diminishing the danger of disease spread while at the same time improving acceptance of the potato. We emphasize that such a comprehensive or integrated approach, similar to that described by Rhoades and Booth (1982), is necessary to overcome limiting factors of a socio-economic as well as of a physical-technological nature.

Limiting physical-technological factors

Many times in its history, the potato has proven its capability to be adapted to different environmental conditions. It moved from the gene-center to the Northern hemisphere, and from the Northern hemisphere to such other parts of the world as southwest and southeast Asia, Africa, and Oceania. This shows that the genetic variability available in the past was sufficient to overcome considerable differences in day-length, temperature, and soil conditions. Of course the potato moved first into the zones with the most convenient conditions for the development of the crop--they are therefore called traditional zones. Why should it not move to the non-traditional zones? In fact, the potato is already on its way. Without going into details (which will partly be given in short contributions), we may say that especially CIP specialists and those cooperating in research contracts with CIP in the past years were quite successful in creating new potato varieties which will be better adapted to non-traditional climates than those available at the present time. However, it is too early to state that the following important limiting factors have been overcome:

- high temperatures, both day and night that reduce net assimilation rates and also reduce the amount of dry matter which is partitioned to the tubers;
- lack of earliness to fit into existing cropping systems;
- susceptibility to late blight, bacterial wilt, bacterial storage diseases, and various insects such as the tuber moth and cutworms;
- uncertainty as to what extent diseases and pests spread out in regions where potatoes never have been grown before;
- potential problems with new insect, disease, or weed pests that are not present in traditional climates;
- limitations due to inadequate soil conditions, such as salinity or aluminum toxicity;
- limitations in yield due to moisture stress as well as to excessive precipitation;
- difficulties in providing vigorous, healthy seed;
- problems in storing and marketing tubers under 'warm' temperatures;
- meeting the preferences of different consumer populations and marketing people for quality of the potato in regard to shape and taste.

Some of the factors on the above list require comment. For example, the need for early maturing cultivars and the need for resistance to late blight are often re-

garded as almost mutually exclusive goals. It was therefore encouraging to find indications of good field resistance to late blight in a number of early maturing neotuberosum clones of the Cornell breeding program for heat tolerance.

Other goals that might prove to be at odds in cultivar development are dormancy requirements for marketing and for seed. Long dormancy would aid in storing ware tubers in order to spread out the marketing season, but one can readily imagine situations where long dormancy could complicate the already difficult problems of growers in warm climates as far as finding quality seed tubers that would be ready for planting.
In fact, however, the major physical problems in storage and marketing tubers in warm climates can be expected to be from insects and diseases rather than sprouting. Resistance to late blight and bacterial wilt should help to reduce such problems; but as long as tubers are handled, stored, and marketed at high temperatures, one can anticipate that various bacteria and fungi frequently will cause serious losses, as will the tuber moth.

Although there are many important factors of a physical nature that pose serious limitations on potato production in nontraditional climates, the essential question is the effect of heat stress on plant growth and development. This topic was recently reviewed at some length (Burton, 1981; Ewing, 1981) and will not be considered here in detail. The main point is that heat stress lowers potato tuber yields both through reduction in the assimilate available for total plant growth and through reduced partitioning of assimilate to tubers.

With regard to assimilate production, the optimal temperature for net photosynthesis is estimated to be less than 25°C. Dark respiration is approximately doubled with each 10-degree C increase in temperature. There is some evidence of an association between heat tolerance and lower rates of dark respiration, but this needs further investigation.

Apparently more serious than the reduction in assimilate that occurs under hot growing conditions is the reduced partitioning of assimilate to the tubers. In this respect, high temperature has a very similar effect to that brought about by long photoperiods. Either high temperature or long days will lead to smaller leaves, more acute leaf angles, longer internodes, more axillary branching, and a smaller percentage of dry matter partitioned to tubers. Long days and high temperatures reinforce each other in these effects, so that high temperatures are more harmful under long days than under short days. (This is fortunate in terms of the prospects for growing potatoes in the tropics.) Light intensity, soil nitrogen supply, and genetic factors also play major roles in determining how photoperiod and temperature will affect partitioning to tubers, and there are doubtless many other factors as well.

Overcoming physical-technological limits

It is understandable that we generally think first of how we can increase yielding capacity and actual yields. We should be careful not to lose sight of the fact that production might be increased just as effectively by reducing losses, whether before or after harvest. In this respect it is essential to think in terms of an integrated production system, including the concept of maintaining soil fertility, as well as integrated pest management.

The use of true potato seed may be of special importance in the lower humid tropics, where it is probably difficult to produce seed potato tubers according to conventional methods. True potato seed either in the form of transplants, direct seeding, or seed tubers could fit into an existing cropping system and probably lower the production costs per unit weight. It is expected that in due time methods will be available to produce real hybrid seed.

Both soil temperatures and air temperatures are important in influencing the growth of the potato, and there is every reason to try to carry out experiments that will ameliorate either in hot climates. Experiments like those already started by CIP scientists on use of companion crops and soil mulches, reflective substances, or other amendments to reduce air and/or soil temperatures should be continued. Water and fertility relations will doubtless be important in this connection, again emphasizing the need for integrated approaches.

Another strategy that may help modify the adverse effects of high temperature on plant morphology is the use of growth substances. High temperatures produce effects similar to the effects of gibberellins, and there is some evidence that compounds working in the opposite direction to that produced by gibberellin might increase partitioning of dry matter to tubers during heat stress (Menzel, 1980). We recognize that hormone applications are likely to be too expensive and sophisticated for needs of developing countries; but the question seems worth pursuing, if only to aid our understanding of the physiological effects of high temperatures.

As mentioned, efforts to breed for heat tolerance have been encouraging. The use of the cutting technique (Ewing, 1981) to screen for both early maturity and heat tolerance has brought good results, but other techniques for rapid screening need to be explored. In order to take full advantage of the potential offered by such breeding programs, we need to understand the physiological basis for heat tolerance. Especially needed is more knowledge about the factors controlling production and partitioning of assimilate to tubers, and the interactions of these factors with environment and genotype. Not only do we need more data about such factors, but we need to be able to integrate the information in such a manner as to make intelligent decisions about the varietal characteristics best suited for particular environments and growing regimes. We know that highest tuber yields are not necessarily associated with the strongest tendency to partition dry matter to tubers. Excessive partitioning to tubers early in the growth of the plant will so restrict root and haulm growth that tuber yields, though early, will be negligible. Highest yields are realized when early growth occurs under low levels of tuber induction so that when strong induction finally occurs there is a large leaf canopy to provide assimilate to the developing tubers.

The complex nature of these relationships has been well described by Moorby and Milthorpe (1975), who point out that the application of simplified growth analysis is therefore meaningless. They also note that once tubers have been initiated, the consequent "sink" effect increases the net assimilation rate, further complicating the picture. Though the "...large degree of plasticity shown by the potato makes this a more formidable challenge than for many other crop species", Moorby and Milthorpe (1975) urge the construction of a quantitative simulation model for potato growth and development to explain these interactions.

An explanatory model for assimilate production and partitioning should prove beneficial in a number of ways:

- It would help identify the cultivar traits that would be best adapted for particular environments and growing seasons. For example, it could help the potato breeder identify in a breeding population those clones that would be best adapted to an 80-day growing season with a 12-hour photoperiod and day-night temperatures ranging from 22 to 37°C, as opposed to clones that would be better suited to conditions with longer days, cooler temperatures, and a longer growing season.
- Conversely, given a particular cultivar with certain morphological and physiological characteristics, the model would help to predict the ideal environment for its growth, the maximum potential yield of the cultivar under ideal conditions, and when it should be planted and harvested. Ability to answer these questions would aid a breeder in deciding whether a breeding line was worthwhile with respect to potential yield, and in which regions or seasons of the year it was likely to be best adapted.
- An explanatory model should help in the prediction of maximum potential yields. Given the ideal combination of traits known to be present in potato breeding populations, what is the maximum yield attainable? Which varietal traits should be chosen, and what are the optimal environmental conditions? Answers to questions such as these could be useful in comparing the maximum potential yields possible among different areas, but also in assessing the most desirable planting and harvesting times for a given area.
- The model can be expected to yield insights into the types of experiments needed to further improve our understanding of carbon assimilation and partitioning in the potato. Loomis et al. (1979) make a persuasive case that one of the most significant benefits of simulation modeling is to help pinpoint the major areas of ignorance that require further attention.

Developing an explanatory model for assimilate production and partitioning in the potato

Loomis et al. (1979) point out the difficulties in employing "...all details available on ecosystem behavior in crop growth models which explore the partitioning of photosynthesis during growth and development." Certainly in the potato the task would be formidable. However, CIP and the organizations present at this Congress offer the kind of framework for cooperation that should make it feasible.

Several attempts at constructing explanatory models for potatoes have already been made (Fukai, personal communication; Ingram, 1980; Ng and Loomis, 1979). However, to accomplish the goals that we have outlined, many more data are needed than were available to those designing the existing models.

The first step should be to study the effects of only one or two environmental factors on assimilate production and partitioning in a group of genotypes. For example, clones known to be tolerant to heat could be compared to heat sensitive clones, with both types grown in warm and cool environments. Necessarily, the initial assumption would be that experiments were carried out under fairly optimal conditions for other environmental factors, such as fertilization, water supply, and pest control. Growth analyses data would be collected from the same clones grown at each location in order to construct a model for the effects of temperature and possibly photoperiod on assimilate production and partitioning in various genotypes under "good" growing conditions. After validation of the model, further studies should be carried out to model the effects of N fertilization, water relations, physiological age of seed tubers, or even effect of growing from botanical seed rather than from seed tubers. Plant population, row spacing, and pest damage would be other important variables to be added eventually.

Clearly, what we propose would require an enormous amount of effort. How could it be accomplished? Before answering this question, it is well to point out that the development of an explanatory model of the type described would be beneficial to producers in traditional as well as in non-traditional climates; the model should prove most useful if broadly based upon data derived from a great range of environments. Therefore it is hoped that researchers in many parts of the world would be willing to participate in gathering the data base required.

Growth analyses studies have already been carried out, or are underway, in many locations. We are aware of such studies in several parts of Europe, the United States, and Australia as well as in such warm locations as lowland Peru and Israel. What is needed is a coordination and expansion of these efforts. One important aim should be to grow the same cultivars or breeding lines at each location. These should include clones known to be tolerant to high temperatures, clones adapted only to cool temperatures, and clones of rather broad adaption such as Desiree and Red Pontiac. In the past such a scheme would have been ruled out of consideration owing to quarantine restrictions. The availability of modern techniques for multiplying and transporting clones in vitro, coupled with ELISA and other sophisticated tests for disease detection, promise to ease the problems of exchanging genetic materials.

Another matter requiring coordination would be the standardization of procedures followed in the collection of growth analyses data. It would not be essential that methodology be identical in all cases, but it would be helpful to agree on the kinds of variables to be monitored and the types of measurements to be taken so that data from the different experiments could be combined.

Locations would need to be chosen to represent a broad cross-section of environments, including those typical of the non-traditional climates for potatoes. It would be essential that personnel and facilities be available at each location to obtain reliable information. (On the other hand, familiarity with computers would not be required--the model building could all be done at a central location from the information supplied.) Also, because of the assumptions in the initial experiments it would be desirable to have conditions such that the principal factor limiting yield would be temperature rather than water relations, pests, aluminum toxicity, or other factors likely to be serious in tropical environments. Bearing these restrictions in mind, a reasonable goal might be to carry out the experiments in three hot locations, in three warm locations, and in three or more locations typical of more traditional growing conditions for potatoes. Further broadening of the data base could be achieved by growing the crops at more than one time of the year or at more than one elevation in each country. Once the model was constructed it would be helpful to test it in new locations for validation purposes.

Perhaps this is a challenge that CIP should consider--to organize the network of locations that would begin to collect the necessary growth analyses data in a unified and useful fashion.

By no means would a successful computer simulation model for assimilation and partitioning in the potato overcome all the factors limiting the extension of the potato into non-traditional climates. However, such a model--modular in design and explanatory in nature--might well provide a useful framework of information from which many of the socio-economic and physical limits could be approached more intelligently.

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POST-HARVEST TECHNOLOGY FOR DEVELOPING COUNTRY TROPICAL CLIMATES

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Summary

The reduction of post-harvest food losses, which are particularly high in perishable crops in developing countries, is important not only from an obligation to avoid waste, but also because the cost of preventing food losses in general is considered to be less than producing a similar additional amount of food of the same quality. In perishable vegetatively propagated crops like the potato, appropriate post-harvest technology is not only required to reduce food losses, but also to maintain the perishable planting material from one growing season to the next.

In the case of potatoes extensive knowledge on basic post-harvest technologies and principles exists. The authors consider that the future emphasis in the use of these technologies in developing country tropical climates should be in their low-cost application to location specific problems. In attempting to use known technologies to solve these problems, lessons should be learnt from many past failures where attempts concentrated on the direct transfer of technologies which were successfully used in one location to a similar problem in another location. Basic technologies and principles are universal but their application is location specific and requires a good understanding of the socioeconomic as well as technical needs of each location. The authors suggest that best use of limited resources in the transfer and application of known technologies could be achieved through the use of interdisciplinary research teams which involve their final client - farmer, merchant or consumer - in their efforts at an early stage, rather than relying on traditional disciplinary research and extension approaches.

As an alternative to trying simply to follow the development path of other countries through the use of high input technologies, the authors suggest that developing countries, in an effort to reduce post-harvest potato losses and to make potatoes available to an increasing number of their peoples in the year 2000, should investigate alternative low-cost application of basic principles.

Introduction

By the year 2000, it is suggested that the world population will increase to between 6 and 7 thousand million. Estimates indicate that between 450 and 1000 million of the present world population do not have

enough to eat, and this number is likely to increase with increased population (NRC, 1977).

To cope with this current and future food demand, governments have emphasized two lines of action: reducing food demand by slowing population growth, and augmenting food supplies by expanding production. There is a third vital measure which until recently has received insufficient attention, and that is to reduce the loss of food after harvest and prior to consumption. Indications are that by the year 2000, 50% more food will have to be available to meet present intake levels and still more if malnutrition and famine are to be conquered (FAO, 1981). Due to the limited availability of land it has been estimated that between 1980 and the year 2000 only about a quarter of the required additional food will be obtained from area expansion (FAO, 1981). To derive the remaining three quarters from more intensive cropping and yield increases will put heavy demands on water, fertilizers, pesticides, energy and managerial skills. Allowing for the increased area, we are talking of overall worldwide yield increases of the order of 30%. Is this realistic? If not, then the case for reducing post-harvest losses or preserving what has already been produced with increasing effort and costs, becomes overwhelming.

In developing countries enormous losses result from spillage, contamination, attack by microorganisms, insects, birds and rodents, and deterioration in storage. To quantify these losses is scarcely possible. Conservative estimates (NAS, 1978) suggest that a minimum of 107 million tonnes of food were lost in the post-harvest system in these countries in 1976, but in our opinion this is probably an underestimate. Although substantial post-harvest losses also occur in developed countries these result in part from somewhat different causes. For instance, many stem from overstrict quality regulations and consumer preferences. Large amounts of food are thus thrown away due to slight changes in quality or appearance. The developed world in general has yet to realize that there is such a thing as shortage of food or, rather, it has forgotten the fact.

This loss of food in the post-harvest system is not new, it has always been a problem for mankind. Yet while billions of dollars have been invested to help developing countries produce more food, this has not generally been matched by investment in, or even by an awareness of the magnitude and importance of the post-harvest loss problem in either developed or developing countries. For example, in 1977 it was estimated that the Agricultural Research Service in the USA invested less than 4% of its budget in food loss programmes (GAO, 1977).

Increased food production alone obviously places strains on existing methods of handling, storing and processing crops. Greater food losses will inevitably result unless countries and donors of economic and technical assistance can establish and maintain adequate harvesting, handling, storage and processing practices; and create efficient policy and administrative infrastructures.

Although some far sighted individuals and organizations have been drawing attention to this problem for many years, international attention has only recently focused on post-harvest loss problems. Attention was drawn to the concept of reducing post-harvest food loss, as a significant means to increase food availability, by the World Food Conference held in Rome in 1974. The VIIth Special Session of the United Nations General Assembly passed a Resolution in September 1975 which focused attention on the problem of post-harvest food losses and which called for concerted action to reduce these losses in the following words:

"The further reduction of post-harvest food losses in developing countries should be undertaken as a matter of priority, with a view to reaching at least 50% reduction by 1985. All countries and competent international organizations should cooperate financially and technically in the effort to achieve this objective."

Those are just words of course. There was not, and is not, the vaguest chance of halving food losses over the ten year period 1975-1985. Nevertheless, as a result of this resolution and an increasing awareness of the magnitude of the problem, a number of national and international donor agencies expanded existing programmes, and initiated new ones, which were directed to the problem of reducing post-harvest losses. Most of these activities have been directed towards reducing losses in cereal grains, oil seeds, and grain legumes; the so call durable crops. Following an initiative by the United States Agency for International Development (USAID) the United States Academy for Science prepared in 1978 a report on the problem of post-harvest food losses in developing countries (NAS, 1978). This report pointed out the need for giving consideration to losses in food products other than the durable crops; particularly roots and tubers, fruits and vegetables; the so called perishable crops.

This report helped stimulate additional activity and increasing numbers of donor organizations and international and national agencies are beginning to consider intervention programmes that can reduce losses in perishable horticultural crops. An example of this increased awareness was the study and expert consultation on food loss prevention in perishable crops jointly organized by the Food and Agriculture Organization (FAO) and the United Nations Environment Programme (UNEP) in 1980, which involved a total of more than 30 specialists. The first of 14 recommendations prepared by this consultation was that:

"An international action programme of post-harvest food loss prevention in perishables of plant origin should be initiated" (FAO, 1981).

This was published in 1981, six years on in that 10-year period in which food losses were to be halved. Four years to go - and by now, three years to go.

The case of potatoes in developing countries

The reported total world production of perishable horticultural crops is over two-thirds that of the staple cereal grains (Table 1). In developing countries the proportion is greater. The total annual production of horticultural crops in these countries has been reported as 620 million tons, equivalent to 85% of the reported cereal production.

Table 1. Production of major food crops. (FAO Production Year Book, 1978).

Commodity	1978 production (million tons)	
	World	D.C.
Cereals	1,580.8	730.6
Roots and tubers	522.8	290.1
Vegetables	327.2	189.2
Fruits	261.9	141.6
Total production	1,112.0	620.9
Commodity	**% of cereal production**	
	World	D.C.
Cereals	100	100
Roots and tubers	33.1	39.7
Vegetables	20.7	25.9
Fruits	16.6	19.4
Total production	70.4	85.0

DC = Developing countries.

These high production figures indicate the important role that horticultural crops play in the economy and nutrition of developing countries, although it must be remembered that these crops are far higher in water content than are the cereals. On a dry matter basis we are thinking more in terms of horticultural crops representing the equivalent of about 20% of the cereal crops in developing countries. This smaller proportion must not be allowed to obscure the fact that the horticultural crops are an essential component of the diet. For example, they provide almost 100% of the vitamin C intake and most of the vitamin A.

On a worldwide basis roots and tubers represent nearly half the horticultural crops, and not far short of half in developing countries. We are not thinking primarily of the potato in this context. It represents only about 10% of the roots and tubers in developing countries. The ten leading horticultural crops in these countries in 1978 are listed in Table 2.

Table 2. Leading horticultural crops in the developing world. (FAO Production Year Book, 1978).

Commodity	1978 production (million tons)
Cassava	110.5
Banana	35.1
Potato	29.5
Citrus	23.9
Plantain	20.4
Yam	20.0
Sweet potato	16.9
Tomato	14.5
Mango	13.5
Grape	11.5

We must, of course, realize that production figures are not accurate. The FAO figure for the production of roots and tubers in developing countries in 1978, for example, was 290.1 million tons (Table 1) - not 290, but 290.1, suggesting an accuracy of 0.3% for a figure which is not a measured amount but an estimate.

Perhaps we should say guesstimate. If we take the estimates at their face value they rank potato as the third most important horticultural crop in developing countries. Of the root and tuber crops produced in developing countries, cassava is the most important in terms of total production, accounting for approximately 40%. Next in volume of production are potatoes, accounting for 10% of total root and tuber crop production. During recent years, incidentally, the production of potatoes in developing countries has increased proportionately more than any other horticultural crop (Horton, 1981). During the period 1965 to 1979 the estimated production of potatoes in developing market economies increased by 107% compared with 47%, 4% and 60% for cassava, sweet potato, and banana, respectively.

Magnitude of post-harvest losses

However, and as we have discussed, not all horticultural production reaches the consumer. Reliable statistics on post-harvest losses in perishable crops are few and for most commodities, including the potato, it is possible to find well recorded individual cases with losses ranging from negligible to 100%. The extent of loss is highly variable depending on a large number of conditions and factors. The National Academy of Science report (NAS, 1978) resisted generalizations of loss estimates, but for planning purposes cited minimum overall post-harvest losses of 10% for durable crops and 20% for perishables. Similarly, for potatoes alone loss estimates vary considerably and few accurate figures of losses measured by a described methodology are available. Nevertheless, the opinion of individuals or groups of professionals with experience of this crop in developing countries give sound indications of normal ranges of loss experienced under usual conditions. Three such post-harvest loss estimates for potatoes include:

i) 5-40% for all developing countries (FAO, 1977).
ii) 25-30% for Chile, Peru and Venezuela (NRC, 1978).
iii) 25% on a global basis (Coursey and Booth, 1972).

The figures are not exaggerated. Estimates of loss in Great Britain, where the climate is not extreme, where problems such as tuber moth are unknown, and where modern technology is available, indicate that some 25% of the crop may be lost in storage. Similar estimates have been made for other developed countries.

While Bourne (1977) correctly points out the possible misleading nature of some arithmetic calculations using these figures, it is nevertheless perhaps worthwhile estimating what they mean in terms of food loss in developing countries. Accepting an average overall post-harvest loss of 25% and personally we would regard this a minimal figure, this means that in 1978 7.4 million tons of potatoes were lost. If these losses through research and development could be reduced by 50% this would make available an additional 3.7 million tons of potatoes equivalent to a 12.5% increase in yield, thus representing 40% of the potato's contribution to the increased supply of food which has been suggested as necessary by the year 2000.

Nature of post-harvest losses

How does the loss occur and what forms does it take? First of all, and most important, rots and destructions caused by diseases and pests can literally cause the total loss of an individual crop. We do not mean blemishes which in the developed world could lead to the tubers being discarded, but which could be trimmed out and the residue eaten. We mean complete destruction by, for example, Erwinia rots, which in extreme cases we have known to cause the loss of several thousand tons of potatoes in a single store. Pests as diverse as rodents and tuber moth can also completely destroy individual tubers.

Secondly, water loss. As a rough rule of thumb guide, you can say that if a tuber is very slightly soft if squeezed between the finger and thumb, then it has lost about 5% of its harvested weight. If it is definitely soft and slightly spongy, then the loss could be 10%. You may say, of course, that this is loss of water and not of food and is not a true loss at all, except to the farmer or merchant who sells potatoes by weight. As a crude approximation, however, you will find that respiratory loss of dry matter roughly parallels loss by evaporation. In other words, if you start with a potato tuber with 20% dry matter and store it until it has lost 10% of its weight by evaporation, you will probably find that its dry matter is still 20%. In such a case, 10% evaporative loss represents also a 10% loss of nutritive material.

The third form of loss results from physiological and biochemical change. In the present context we may disregard changes which adversely affect the finer shades of quality, but we cannot disregard changes which lead to sprout growth. Five or ten percent of sprouts - and you can get as much as this - represent a 5% or 10% storage loss quite apart from the enhanced rate of evaporation caused. And in case any of you are tempted to say, that in the developing world nothing is wasted, and the sprouts could be eaten, we should point out that one of the very few recorded deaths from solanine poisoning was that of a man who had eaten potato sprouts fried in oil.

What research is needed to reduce post-harvest losses?

First of all, research in phytopathology, entomology and breeding is required. The breeding of a variety which was really field resistant to late blight for example, could not only have important effects on increasing yields in the highland tropics - it could also reduce storage losses ultimately attributable to blight. Reduction of tuber moth infestation would also reduce losses attributable to it. Not, we hasten to say, by chemical control. Many of us no doubt have seen hair-raising amounts of toxic chemicals applied to tubers in countries where there are no strict controls on food additives.

We are neither pathologists, entomologists nor breeders, so we should not dare to predict the influence of these disciplines on storage losses by the year 2000. We think considerable progress will have been made in the necessary research. We do not know if it will have been applied but we will have more to say about application later.

As far as water loss is concerned, the principles are known. One might conceivably suggest a breeding input in increasing the thickness of periderm if this were acceptable on other grounds, although we should say that the relationship between periderm thickness and water loss is hypothetical rather than established. We would not look to a breeding input to have much effect upon water loss by the year 2000.

Sprout growth in the developed world is often suppressed chemically, a method which, like the chemical control of pests, can lead to residue problems if it is uncontrolled. As opposed to sprout suppression, sprout stimulation may be desirable in seed tubers, particularly if two crops are grown in a year. This too is done chemically. The search for better methods of sprout suppression and stimulation will doubtless continue. Both are needed, but we doubt whether any positive research findings will have a practical application in developing country tropical climates by the year 2000. Nor, we suspect, will there be by then any practical spin-off from the much-needed establishment of the detailed biochemistry of dormancy and growth, even if this has been achieved.

What we are saying is that reduction of post-harvest losses by the year 2000 will not depend to any great extent upon research initiated now or which is in progress now. It will depend upon the application of results already obtained.

Application of existing knowledge: closing the transfer gap

Post-harvest technologies for reducing loss can generally be considered under three headings: handling, storage and processing. In our present context, processing should only consider primary processing whereby the potatoes are converted by a series of steps into a basic edible commodity. These steps commonly involve weight loss and may or may not involve food loss, depending upon whether the loss is water or nutritive matter. Also in the case of vegetatively propagated crops like the potato, storage and handling of the perishable planting material deserves specific attention, not only as a means of reducing losses but also as a means of improving production.

In attempting to develop or apply post-harvest technologies to reducing food loss in developing countries it must always be remembered that cultural, economic and social, and political factors strongly affect the nature and magnitude of food loss and the attitudes of farm families and governments to food conservation. Even the perception of what constitutes food loss often varies greatly among cultures and with time. Losses may affect the subsistence farmer, the farmer who produces food for sale, merchants, and consumers. Although any losses will ultimately be felt by society as a whole, individual groups are likely to experience the economic and social consequence to different degrees. Many kinds of costs may be associated with post-harvest losses, and it is important to assess these costs as thoroughly as possible for an accurate picture of possible economic and social consequences. Further, strategies to prevent or reduce food losses have economic and social effects not only on consumers and producers, but also on other groups involved in the food chain. Expe-

rience has thus demonstrated that any food loss programme must be sensitive to the cultural, socioeconomic and political characteristics of a society and be aware that the technical and scientific components of change cannot be divorced from these considerations.

Accepting this broad view of the utilization of technologies in food loss programmes the question arises as to whether the post-harvest losses in potatoes in developing countries are the result of unavailable or inadequate technologies or due to the failure to apply existing and available technologies correctly. Judging from the amount written on the subject in the scientific literature one must conclude that considerable information and technologies are available. Considerable attention is given to storage and processing technologies in several major books on potatoes (Burton, 1966; Smith, 1977) and several books have been published on these topics alone (Talburt and Smith, 1975, Cargill, 1976; Rastovski et al., 1981; Booth and Shaw, 1981). Also during the five year period 1976 to 1980 the average annual number of citations under the heading of Harvesting, Storage and Quality and Food Technology in the Commonwealth Agricultural Bureaux Potato Abstracts were 84 and 155, respectively, as compared with 137, 123 and 356, respectively, under the heading of Breeding & Selection, Agronomy and Diseases and Physiological Disorders. This extensive literature confirms the authors' opinion that adequate basic technologies and scientific information are currently available to solve many of the post-harvest potato problems in developing countries if these were or could be appropriately applied.

If the application of known post-harvest technologies is an appropriate means of conserving potatoes, why does a gap exist between the establishment and use of technologies in developing countries? The authors consider that there are three major reasons for this.

Firstly, proposed technical solutions are frequently simply copied or borrowed from developed country literature or experiences rather than creatively adapted to the realities and needs of the specific situation. Unfortunately, too many scientists working in agricultural development, commonly of developed country origin, training and experience, still hold the view that if technology is successful in one location, usually in a developed country, then it will automatically be successful in any technically similar developing country situation. They fail to realize that while the principles of a basic technology may be universally transferable, the application of these principles is location specific and must carefully consider the prevailing environment and system to which they are being applied. In other words a post-harvest system was already in existence and any proposed changes must accommodate to that and other systems which it influences. Many examples of this type of misplacement of technologies can be found; for example, in the large number of technically sound, but continuously empty, potatoes stores that are to be found in the developing world.

Secondly, there is frequently not adequate incentive for individuals to invest in post-harvest technologies. Producers are unlikely to invest money or effort in loss reduction activities unless they foresee a good return whether in income, security or status. This lack of incentive is frequently linked with aspects of government politics and policies. For example, certain types of price fixing, credit laws, and laws against storage of foods for speculative reasons provide little incentive for crop storage, and commonly subsidised imports of cereal grains provide little incentive for simple primary processing of potatoes into flour or starch.

Thirdly, the decisions in the less well developed countries to store and/or process a crop to minimize losses, stabilize prices, or to make food available at a later time are typically made by administrators who commonly do not have, and do not refer to, adequate technical and socioeconomic understanding and knowledge. Well-intentioned policies thus frequently fail. Actual loss reduction efforts must begin with political committment by individual countries to understand and to carry through the necessary actions required at the national level.

Post-harvest research scientists commonly place the blame for the transfer of technology gap either singularly or jointly on poor extension services and backward farmers. They look for solutions by talking about the need for improvements in conventional country extension and communication programmes. The farmers, of course, will respond about the inappropriateness of the technologies to their specific needs. The authors believe that research scientists themselves must accept greater responsibility for this problem and re-orientate their efforts to solving specific problems in addition to adding to the scientific literature. To achieve this it is considered appropriate that the investigation of the application of post-harvest technologies be organized in small interdisciplinary teams with specific problem solving objectives and accepting that success will be measured by the degree of acceptance and utilization of introduced changes. The fact that the farmer, merchant, or consumer will be the final evaluators of the team effort will hopefully influence its members to view the research and transfer of technology processes, at least in part, from the viewpoint of the final client. To help make this a greater possibility it is further suggested that such teams comprise not only post-harvest biologists, engineers, and food scientists, but also social scientists and marketing economists. The inclusion of the social sciences in the team should broaden the understanding of the factors, other than strictly technical considerations, which will influence the acceptance or rejection of proposed technological changes and thus enable a better understanding and diagnosis of the problem to be achieved. By continuous interaction throughout the research and technology transfer activities it is considered that better use can be made of limited resources - an important consideration for the year 2000.

An additional factor which needs to be incorporated into such interdisciplinary team approaches is that of maximum involvement of the final client - farmer, merchant, consumer, or government. This involvement should be sought at an early stage if adequate problem diagnosis is to be achieved and can beneficially continue throughout the entire problem solving processes. The authors strongly support the view recently expressed simply by CIMMYT: "Tell me, I'll forget; show me, I may remember; but involve me and I'll understand" (CIMMYT, 1981). Too often research and development scientists believe they know what is best for their clients, but how often do they spend time to go out and find out what the client thinks about his problem and solicit his assistance in developing improvements?

This approach has been the basis of the small post-harvest interdisciplinary team at the International Potato Center (CIP), where to-date emphasis has been placed on low-cost seed stores and village level processing. Using this approach simple low-cost natural diffused light seed stores have been developed and transferred to farmers in many developing countries. Similarly, a simple pilot processing plant to upgrade the traditional means of producing dried potato and starch is being accepted in Peruvian communities and tested in other countries.

Resulting from an analysis of their efforts the team developed a "Farmer-Back-to-Farmer" model to describe the interdisciplinary team approach for generating acceptable agricultural technology (Rhoades et al., 1981; Rhoades and Booth, 1982). The underlying thesis is that applied agricultural research purposing to generate acceptable agricultural technology must both begin and end with the farmer or other client.

Post-harvest technologies for the year 2000

In considering what specific types of post-harvest technologies will be needed and which will be relevant and potentially acceptable to potato production systems in tropical climates in developing countries in the year 2000 two somewhat opposing approaches could be considered.

On the one hand we might assume that standards of living in developing countries will continue to rise and create a demand for the types of technologies that are presently in place in more developed countries. These would include increased sophistication throughout the marketing chain and particularly in product harvesting and handling and an increased use of specifically designed and constructed sophisticated storage units. There would also be an increased demand for convenience foods and the generally high cost technologies required to produce such products. Such processing systems require a high capital input, high energy inputs, high management inputs, expensive packaging and frequently create high waste. The consequences of this type of post-harvest technological expansion in developing countries would almost certainly be increased unit costs of both fresh and processed potatoes. In any case, the authors regard this approach as unrealistic, although no doubt it will be followed in many cases. A large unused refrigerated store is a more obvious status symbol, both for the recipient country and for the donor agency, than a number of small simple on-farm stores. The approach is unrealistic because supplies of many of the components of the sophisticated systems are becoming scarcer and more expensive, for example energy.

An alternative approach, generally favoured by the authors, is that to assist in making potatoes, a valuable world food,

more available, alternative low-cost technologies must be sought. The dangers of attempting to follow and copy the high input, high cost technologies of more developed countries should be avoided. Thus, research is required to apply the known basic principles to the development and application of low-cost technologies.

The low-cost storage needs can be classified as those appropriate for seed tubers or consumer potatoes, and which are applicable in the three general storage climates that are encountered in tropical developing countries. These are the traditional cool potato climates found in the highland tropics, and the hot and dry, and hot and humid climates found at lower altitudes. By and large, low-cost storage technologies for the cool regions are readily available for both seed and consumer potatoes although these are generally not optimally applied. The problem of technology transfer has been discussed and it is considered that in the case of consumer potatoes it is government policies and lack of understanding of the post-harvest needs of the total production/supply/demand system which creates a lack of any kind of incentive for post-harvest actions. This is possibly the major constraint to be overcome if significant progress is to be made by the year 2000. In the case of improved low-cost seed storage for cool regions the situation is somewhat simpler as the incentive to improve his seed exists at the individual farmer level. The recent advances made by the International Potato Center in researching, adapting and transferring the diffused light seed storage technology is an example of what can be achieved through a balanced interdisciplinary approach.

For the hot-dry and hot-humid areas low-cost storage technologies are less readily available, and increased research is required to develop low-cost alternatives, particularly the application to potato storage of lower cost cooling systems such as evaporative cooling in hot-dry areas. Also lower cost means of applying presently available refrigeration systems, possibly through the use of lower cost constructions using locally available traditional building materials. At the technical level the problem of seed tuber storage may be more readily overcome as it has been shown at CIP (CIP, 1979) that seed tubers stored in diffused light can be kept in acceptable physiological condition for 4 to 6 months at average storage temperatures of 20° to 25°C, provided that important pests and diseases, particularly potato tuber moth, are controlled. In undertaking this technological research on storage technologies for hot regions emphasis should simultaneously be placed on discovering the clients' needs as a means to reduce the transfer gap.

Dehydration or sun drying is the simplest and lowest cost method of processing and preservation. Wherever dried or simply cooked and dried products are acceptable either directly for food or for secondary processing into needed products this simple type of processing should be encouraged. This type of processing can ideally be used to upgrade the value of otherwise low grade tubers, eg. small and damaged tubers. By these simple methods tubers can be converted into stable items with long storage life and which can readily be transported.

In addition to the encouragement of this simple type of primary processing at the farm or community level, the development of alternative and possibly somewhat more sophisticated systems may be required for regions where solar drying is not feasible in the available processing season and where large quantities of potatoes are produced in a short period which cannot be absorbed by the fresh market, stored, or processed by the above simple means. This commonly occurs, for example, when immature tubers are harvested out of paddy fields prior to rice planting. Such processing methods should if possible also be relatively low in capital and energy requirements to enable them to be used economically for short periods of the year. Alternatively the methods used should be applicable to other crops to enable the plants to be used for a greater proportion of the year.

Also, the known basic technologies for the secondary processing of primary potato products into food items need to be made available in appropriate forms for use in developing countries.

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POTATO PRODUCTION AND UTILIZATION IN WORLD PERSPECTIVE WITH SPECIAL REFERENCE TO THE TROPICS AND SUB-TROPICS

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Summary

In the tropics and subtropics potato production is increasing rapidly, while in temperate-zone industrial countries production is declining gradually. It is not expected that in countries with market economies potatoes will be grown for ethanol production (as a source of energy) in the near future. An increase in potato production for starch or stock feed is also unlikely, unless grain prices increase sharply. Since per capita potato consumption is rather stable in the temperate zone, the area under potatoes may be expected to decline slowly as yields increase.

Potato consumption is increasing rapidly in many parts of the tropics and subtropics, where average consumption is still low. This is especially the case in Africa and the Far East. One important reason for the low level of per capita potato consumption in developing countries is the high retail, or consumer, price of potatoes.

The high price is, in turn, due largely to high production costs. On the average, energy and protein derived from potatoes

cost the developing country consumer about three times or more than energy and protein from wheat and rice. As a consequence, potatoes are consumed as a vegetable rather than a staple food in most developing areas.

Continued rapid expansion of potato production and consumption will require a substantial reduction of unit production costs and retail prices. Better application by farmers of existing and newly developed technologies - including better adapted varieties, healthy seed tubers, botanical seed, and low-cost storage and processing - would allow potato production costs to be reduced substantially. This, in turn, would allow the potato to become a major vegetable in many tropical and sub-tropical areas where it is presently of minor importance, and a staple food in some areas where it is now a vegetable. To achieve this by the year 2000, potato yields must be doubled in all tropical and sub-tropical countries and area under potatoes in Africa and the Far East must also be doubled.

Introduction

This paper: outlines the present situation of world potato production and use; looks to possible future developments; and analyzes potential for expansion of potato production and use in the tropics and sub-tropics.

While it is impossible to predict accurately future events, we attempt to draw conclusions about likely developments. Some are bound to be controversial. We present them in order to stimulate discussion and further research and development programmes which will lead to greater use of the potato as a world food crop.

Present situation

Production

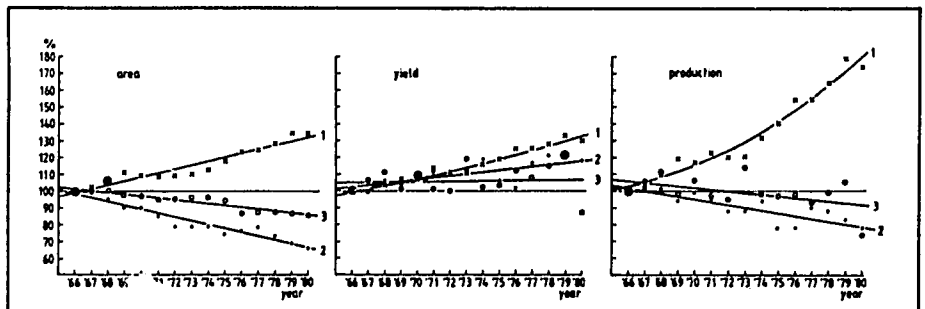
Area, yield, and total production: FAO statistics, Figures 1 and 2, illustrate trends in world potato production, area, and yield in different regions and types of economy from 1966 to 1980. Over this period the area under potatoes in North America and Western Europe decreased annually by more than 2% and yield increased by almost 1%. Consequently, over the period total production decreased by about 20%. In Eastern European and Asian countries with centrally planned economies area cropped to potatoes decreased annually by 1% and yield increased slightly less than 1%, so that total production remained about constant.

Quite different is the situation in developing market economies. Since 1966 both area under potatoes and yield per ha increased annually by over 2%. Consequently, total production nearly doubled. The area under potatoes in Africa and Asia increased by almost 7% and 4% per year respectively, while that in Latin America did not change substantially. Potato yields increased annually by more than 2% in Latin America and in Asia, while in Africa yields remained constant. In the developing countries of all three regions total production increased considerably. During this period, production doubled in Asia and Africa, and increased by 40% in Latin America (See World Potato Facts, CIP, 1982).

Production comparisons: Changes in yield and production of wheat, rice, and maize in developing market economies are shown for the same period (1966-80) in Figure 3. The area under wheat has increased annually by about 2%, while the area under rice and maize has increased by less than 1%. The yield of wheat increased annually by more than 3% and that of rice by almost 3%. The yield increase of maize has been no more than about 1%. Due to these changes in seeded area and yield, it follows that from 1966-80 production for wheat, rice and maize has increased by about 100%, 60%, and 30%, respectively.

From 1966 to 1980 annual percentage increases in total rice and potato yields have been about equal, while the percentage increase in wheat yield has been higher. But in the same period the increase in edible energy and protein yield per ha was slightly higher for potatoes than for wheat and rice (Figure 4). This is despite the widespread adoption of the "miracle, high yielding" wheat and rice varieties. If we extrapolate the 1966-80 trend to the year 1990, the increase of edible energy produced by potatoes per ha would be almost double that of wheat and rice.

Per capita potato production: National estimates of per capita potato production indicate importance of the crop in various parts of the world (Table 1). While in Eastern Europe (the main potato producing countries) a large part of the crops is



1) $\hat{y} = 2132 + 51.7x$ ($100 = 2208 \times 10^3$ ha) $r = 0.96$

2) $\hat{y} = 4153 - 94.6x$ ($100 = 4133 \times 10^3$ ha) $r = -0.97$

3) $\hat{y} = 14624 - 1[illegible].0x$ ($100 = 14223 \times 10^3$ ha) $r = -0.95$

1) $\hat{y} = 7.89 + 0.1427x + 0.0030x^2$ ($100 = 8.1$ t/ha) $r = 0.98$

2) $\hat{y} = 20.09 + 0.22x$ ($100 = 19.8$ t/ha) $r = 0.74$

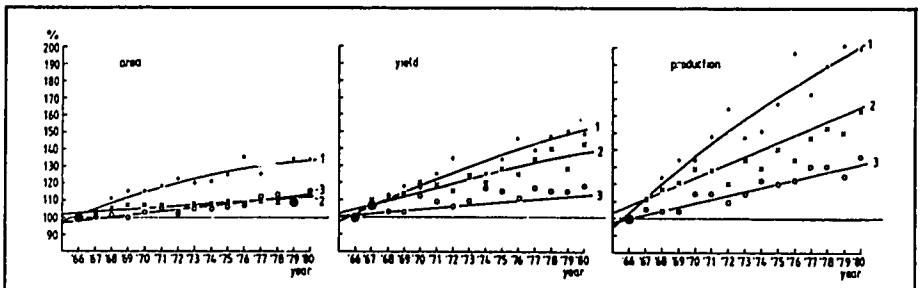
3) $\hat{y} = 12.55 + 0.02x$ ($100 = 12.0$) $r = 0.10$

1) $\hat{y} = 17968 + 285.16x$ ($100 = 17810 \times 10^3$ t) $r = 0.98$

2) $\hat{y} = 84358 - 1300.7x$ ($100 = 87125 \times 10^3$ t) $r = -0.34$

3) $\hat{y} = 183696 - 1787.7x$ ($100 = 170499 \times 10^3$ t) $r = -0.51$

Figure 1. Development of the area cropped, yield and total production in: (1) developing countries with market economies; (2) North America and Western Europe; and (3) countries in Eastern Europe and Asia with centrally planned economies (Data from FAO Production Yearbooks).



1) $\hat{y} = 1063 + 0.80x$ ($100 = 1033 \times 10^3$ ha) $r = 0.10$

2) $\hat{y} = 199 + 15.9x$ ($100 = 214 \times 10^3$ ha) $r = 0.99$

3) $\hat{y} = 967 + 1.064x + 2.119x^2$ ($100 = 961 \times 10^3$ ha) $r = 0.98$

1) $\hat{y} = 7.35 + 0.1963x - 0.0012x^2$ ($100 = 7.4$ t/ha) $r = 0.93$

2) $\hat{y} = 6.66 - 0.00x$ ($100 = 7.0$ t/ha) $r = 0.07$

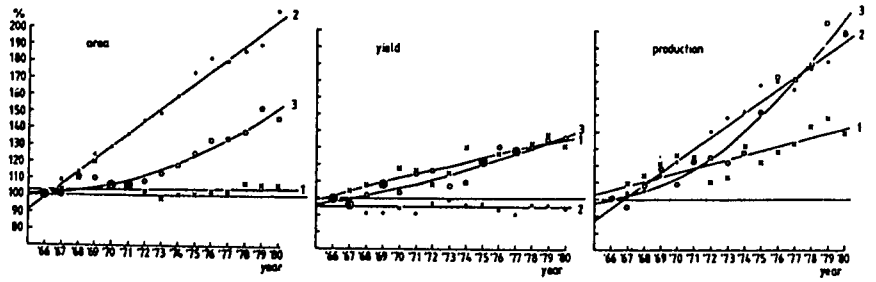
3) $\hat{y} = 8.71 + 0.1557 + 0.0063x^2$ ($100 = 9.1$ t/ha) $r = 0.94$

1) $\hat{y} = 7856 + 197.2x$ ($100 = 7607 \times 10^3$ t) $r = 0.86$

2) $\hat{y} = 1317 + 105.6x$ ($100 = 1494 \times 10^3$ t) $r = 0.99$

3) $\hat{y} = 8560 + 68.1x + 37.9x^2$ ($100 = 8709 \times 10^3$ t) $r = 0.98$

Figure 2. Development of the area cropped, yield and total production in (1) developing countries in Latin America; (2) developing countries in Africa; (3) developing countries with market economies in Asia (Data from FAO Production Yearbooks).



1) $\hat{y} = 49.52 + 1.985x - 0.054x^2$ ($100 = 50.5 \times 10^6$ ha) $r = 0.96$

2) $\hat{y} = 87.70 + 0.59x$ ($100 = 86.2 \times 10^6$ ha) $r = 0.89$

3) $\hat{y} = 49.24 + 0.52x$ ($100 = 50.6 \times 10^6$ ha) $r = 0.94$

1) $\hat{y} = 0.934 + 0.0414x - 0.0005x^2$ ($100 = 0.95$ t/ha) $r = 0.96$

2) $\hat{y} = 1.590 + 0.0401x - 0.0002x^2$ ($100 = 1.55$ t/ha) $r = 0.93$

3) $\hat{y} = 1.20 + 0.01x$ ($100 = 1.19$ t/ha) $r = 0.88$

1) $\hat{y} = 45.89 + 4.2206x - 0.0546x^2$ ($100 = 48.2 \times 10^6$ t) $r = 0.96$

2) $\hat{y} = 139.45 + 4.48x$ ($100 = 133.7 \times 10^6$ t) $r = 0.92$

3) $\hat{y} = 59.13 + 1.39x$ ($100 = 60.4 \times 10^6$ t) $r = 0.95$

Figure 3. Development of the area cropped, yield and total production of: (1) wheat; (2) rice; and (3) maize in developing countries with market economies.

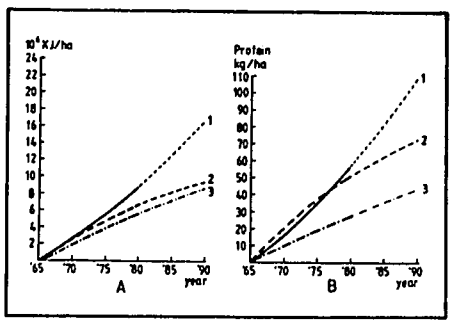


Figure 4. Accumulated calculated increase in yield (after 1980 extrapolated) expressed in terms of energy (A) and protein (B) for (1) potatoes, (2) wheat, and (3) rice (70% edible) in developing countries with market economies and based on the regression curves given in Fig. 1 and 3 (For energy and protein value see Table 7).

Table 1. Per capita potato production 1978 1/.

Regions	kg
WORLD	66
Developed countries	
North America	79
Western Europe	143
Eastern Europe (including USSR)	415
Developing countries with market economies	
Latin America	32
Africa	9
Near East	26
Far East	9

1/ From International Potato Center, 1982.

still used for stock feed, and in a few countries (e.g., the Netherlands) a share are grown for starch production, in most of the world potatoes are primarily for human consumption.

In developing countries per capita production is much lower than in the industrialized countries, although higher in Latin America and the Near East. In most African and Far Eastern countries the crop is still quite small, relative to major staples (Table 2). Over the last 15 years increase in per capita production has been striking in many developing countries. In fact, the average growth rate of potato production exceeds that of most other food crops in the developing countries.

Energy requirements and efficiency of energy conversion: Potatoes can produce more edible energy and protein per ha than practically any other food crop. In terms of energy and protein production per day the potato also ranks high (Van der Zaag, 1976). High potato yields require a large input of energy per hectare. Data from Pimentel (1975) and Heichel (1975) indicate that under US conditions, the potato crop requires more energy input per ha than most cereal crops. The energy input for potatoes is exceeded only by that of irrigated rice and high value vegetable crops such as broccoli and cauliflower. The potato crop is a heavy user of energy derived both from fossil fuels and human labor (Table 3).

Among crops, potatoes occupy an intermediate position between the cereals and most vegetables in efficiency of energy conversion. Heichel's US data (1975) indicate that potatoes are more efficient in energy conversion than most other vegetables and fruits but less efficient than most cereals and soybeans. Pimentel (1975) has shown that, again under US conditions, the potato crops is more efficient than bean, rice, and wheat in converting energy derived from fossil fuel into food energy, but less than oats, maize and soybean (Table 3).

Energy budgets are not available for many crops grown in developing countries (see Pimentel 1974, 1975, Leach, 1976, and Cox and Atkins, 1979). We have developed energy budgets for the potato crop for different locations in Peru, the Philippines and Rwanda, and compared these with

Table 2. Average per capita potato production 1978-1980 in developing countries with more than 5000 ha potatoes and percentage change in relation to 1961-65 1/.

Countries	Total production (10^3 tonnes)	Per capita production (kg)	Increase or decrease (-) (%)
Central America			
Cuba	211	21	177
Guatemala	50	7	65
Mexico	82	12	128
South America			
Argentina	1618	61	-8
Bolivia	719	136	33
Brazil	2032	17	64
Chile	885	81	1
Colombia	2010	77	177
Ecuador	286	37	-34
Peru	1636	95	-7
Uruguay	337	35	61
Venezuela	214	15	172
Africa			
Algeria	491	27	123
Angola	38	6	108
Burundi	22	5	-75
Cameroon	100	12	498
Egypt	983	24	269
Ethiopia	233	7	78
Kenya	360	23	72
Libya	94	32	725
Madagascar	212	25	218
Malawi	110	19	134
Morocco	327	17	143
Mozambique	56	5	304
Rwanda	228	50	304
Tanzania	85	5	345
Tunisia	117	19	175
Uganda	330	26	165
Zaire	31	1	69
Asia			
Afghanistan	252	12	50
Bangladesh	907	11	196
Bhutan	42	32	175
Cyprus	205	342 2/	117
India	8855	13	182
Indonesia	222	2	227
Iran	695	19	105
Iraq	105	8	841
Lebanon	109	23	143
Nepal	292	21	24
Pakistan	38	5	320
Syria	224	27	569
Turkey	2973	67	120
Vietnam	717	12	>1200
Yemen Arab. Rep.	113	19	201

1/ From FAO Production Yearbook 1981.

2/ Mainly export.

the US budget presented by Pimentel (1974) and the Netherlands budget by Van der Zaag (1978). These budgets illustrate a wide range of possible production technologies, energy use and yields (Table 4). Where yields are highest, energy inputs in the form of chemical fertilizers and pesticides account for a large proportion of the total energy input. In general, the energy conversion ratio is higher for traditional systems, based on hand labor (highland Peru and Rwanda) than for modern systems based on fossil fuels (coastal Peru, the Philippines, the USA, and the Netherlands). On the other hand, the net energy output (output-input) is generally higher for modern systems than for traditional ones.

Table 3. Analysis of protein and energy production for various crops in the United States[1].

Crop	Crop yield/ha			Energy inputs/ha for production		Output per unit fossil energy input	
	Total (t)	Protein (kg)	Food energy (..... GJ.....)	Fossil energy	Labor (manhours)	Protein (g/MJ)	Energy (GJ/GJ)
Soybeans	1.9	640	31.8	22.2	15	28.7	1.4
Brussel sprouts	12.3	604	23.0	35.6	60	16.7	0.6
Potatoes	26.2	524	84.5	37.2	60	14.3	2.3
Corn	5.1	457	74.9	27.6	22	16.7	2.7
Rice	5.8	380	87.9	64.9	30	4.8	1.4
Dry beans	1.4	325	20.9	18.8	15	16.7	1.1
Oats	1.9	276	31.0	12.6	6	21.5	2.5
Wheat	2.3	274	31.4	15.9	7	16.7	2.0

1/ From Pimentel 1975.

Table 4. Energy budget in gigajoules (GJ) for the potato crop in selected countries[1].

	Peru[1]			Philippines 2/	Rwanda 3/	U.S.A. 4/	Netherlands 5/
	Highland		Coastal				
	High input	Traditional					
Labor	1.02	0.95	0.43	1.24	1.35	0.14	0.08
Oxen	0.35	-	1.44	-	-	-	-
Seed	9.33	5.30	9.75	4.82	3.97	1.13	6.20
(1) Sub-total	10.71	6.25	11.62	16.05	5.32	1.26	6.28
Tractor and Equip.	0.82	-	-	-	0.11	12.43	21.86
Fertilizers: N	24.30	2.58	12.30	6.70	-	10.88	
P	1.88	0.61	2.08	6.70	-	3.42	35.79
K	1.18	0.23	0.62	1.39	-	2.29	
Pesticides	1.29	0.34	0.31	0.10	-	1.70	2.28
(2) Sub-total	29.48	3.76	15.31	14.89	0.11	30.73	59.93
(3) Total input	40.19	10.01	26.93	30.95	5.43	31.99	66.21
(4) Gross energy output	69.32	23.21	53.74	63.60	19.08	82.48	149.70
(5) Net energy output (4)-(3)	29.13	13.20	26.81	32.65	13.65	50.48	83.49
Gross energy output per unit non-renewable energy (4)/(2)	2.35	6.17	3.51	4.27	173.45	2.68	2.50
Gross energy output per unit total energy input (4)/(3)	1.72	2.32	2.00	2.05	3.51	2.58	2.25
Yield (t/ha)	21.8	7.3	16.9	20.0	6.0	25.6	41.0

1/From unpublished International Potato Center estimates; 2/PCARR, 1979; 3/Durr, 1980; 4/Pimentel, 1974; 5/Van der Zaag, 1978.

The capacity of the potato crop to yield a large volume of energy per ha and per day is an asset where cropland is scarce. On the other hand, the dependence of high potato yields in modern systems on energy inputs derived from fossil fuels is a liability of the crop.

Production costs: Comparable data from many countries on production costs and returns for a range of crops have not been published to date. We have estimated production costs for potatoes, wheat, rice, and sweet potatoes, based on FAO estimates of farm-level prices and yields (Tables 5 and 6). Table 7 summarizes production costs estimated by leaders of National Potato Programmes in many developing countries. Table 8 presents similar estimates from the Netherlands.

From all these data it can be concluded that in developing countries production costs for sweet potatoes, rice, and wheat, expressed in kg dry matter or in terms of energy, are considerably lower than production costs for potatoes. In the Netherlands, in sharp contrast, average production costs of energy or protein from potatoes do not differ greatly from those for wheat. The production cost for wheat is similar in the Netherlands and in developing countries, while the production cost for potatoes is twice as high in developing countries than in the Netherlands.

In developing areas production costs often vary with altitude. In Kenya, for example, at high altitudes the cash expenses for maize and potatoes are about equal while at mid-elevation maize is considerably cheaper than potatoes (Table 9).

Estimated potato production costs for several countries are presented in Tables 10-12. These estimates indicate that, in general, seed potatoes are the single most costly production input. In South America and tropical Africa seed accounts for 20-40% of the direct production cost; in Asia 30-35%; and in Central America around 50%. In developing countries, labor tends to be the second most important input in the cost structure, accounting for 15-35% of total production cost in most cases; in Kenya and Rwanda labor constitutes over half the total production cost. Inputs of industrial origin - equipment and fuel, chemical fertilizers, and pesticides - account for a very small proportion of the total production cost in the African countries studied (practically 0% in Rwanda and 17% in Kenya) and between 20% and 40% in the Asian an Latin American countries.

In the US and the Netherlands the structure of potato production costs differs considerably from that of developing countries. In these 2 cases, seed and labor account for only 20 and 8% of the production cost, respectively, and inputs of industrial origin account for nearly 75%.

From the above, it can be seen that power (labor and/or machinery), seed potatoes, and fertilization form an important part of the cost of potato production in all world regions. Later in this paper, when possibilities to reduce production costs are discussed, we will concentrate on these three items.

While the structure of production cost varies considerably between countries, the total cost for most countries is between US$1,000 and US$2,000/ha. This cost level is considerably higher than that for other major foodcrops, such as rice, wheat, and sweet potatoes (Table 5). Thus, the potato crop is generally a high-input and high-output foodcrop in all world regions. Both potato yields and production costs/ha are higher in developed countries than in

Table 5. Production cost (US$/ha) for potatoes, wheat, rice, and sweet potato in Africa, Latin America and the Far East 1977[1] based on the assumption that production cost is 0.9 farm-level price.

Area and (number of countries)	Potato	Wheat	Rice	Sweet potato
Africa (10)	1,018	131	293	597
Latin America (7)	1,274	227	315	702
Far East (9)	1,830	192	312	652

1/ From unpublished estimates of FAO Basic Data Unit.

Table 6. Production cost per kg dry matter (US$) for potato, wheat, rice and sweet potato in some regions 1977 1/.

Developing market economies	Potato	Wheat	Rice	Sweet Potato
Africa	0.78	0.22	0.25	0.34
Latin America	0.67	0.21	0.20	0.33
Far East	0.86	0.16	0.17	0.30

1/ Data from Table 5.

Table 7. Production cost and consumer price of potatoes, wheat, and rice per ha and per unit energy and protein in developing countries[1].

Crop	Average yield 1978-80 (t/ha)	Production cost in US$ per			Consumer price in US$ per	
		ha	10^6 kJ energy[2]	1 kg protein	10^6 kJ energy	1 kg protein
Potatoes	10.5	1524	47	7	97	15
Wheat-bread	1.4	252	14	2	47	5
Rice	2.1[3]	382	18	4	37	7

[1] From Horton, 1983.

[2] Potatoes US$ 0.30/kg 100 g = 310 kJ; protein 2%
Bread US$ 0.43/kg 100 g = 907 kJ; protein 7.9%
Wheat 100 g = 1297 kJ; protein 10%
Rice US$ 0.52/kg 100 g = 1415 kJ; protein 7%.

[3] 70% edible.

Table 8. Production cost and consumer price of potatoes, wheat and sugar-beets per ha and per unit energy and protein in the Netherlands[1].

	Average yield (t/ha)	Farm cost in US$ per			Consumer price[2] in US$ per	
		ha	10^6 kJ energy	1 kg protein[3]	10^6 kJ energy	1 kg protein
Potatoes	45	2500	18	3	81	13
Wheat-bread	6.5	1400	17	2	116	13
Sugar-beets-sugar	50[4]	1900	14	-	51	-

[1] From Anonymous, 1981.

[2] Pre-packed potatoes US$ 0.25 per kg (strong fluctuations)
brown bread US$ 1.05 per kg
sugar US$ 0.85 per kg; 100 g = 1673 kJ.

[3] Energy and protein for potatoes, wheat and bread see Table 7.

[4] Sugar 8 t/ha.

Table 9. Comparison of cash expenses and energy and protein production for maize and potatoes at two altitudes in Kenya[1].

Crop	Yield (kg/ha)	Vegetative period (days)	Cash expenses (Ksh/ha)	Energy[2] production day^{-1} ha^{-1} (10^3 kJ)	Protein[2] production day^{-1} ha^{-1} (kg)	Cash expenses in Kenyan shillings per	
						10^6 kJ energy	1 kg protein
				1700 - 2300 m			
Maize	1350	150	1200	135	0.9	59	9
Potatoes	7200	120	2800	158	1.0	148	23
				>2300 m			
Maize	900	300	1300	45	0.3	96	15
Potatoes	11000	150	2900	193	1.2	100	16

[1] From unpublished data provided by J.K. Sirror; Van der Zaag, 1982a.

[2] Potatoes 100 g = 310 kJ; 2% protein (85% edible).
Maize 100 g = 1498 kJ; 9.5% protein.

developing countries. But since the yield gap between these 2 groups of countries is greater than the percentage difference in production costs/ha, potato production costs per kg output are higher in developing countries than in developed countries.

Utilization

Utilization in general: Accurate estimates of world potato utilization are not available. A very rough estimation for world regions, based on FAO data, is presented in Table 13. A substantial part of the world crop - nearly one third - is used for fodder. Some Western European countries previously grew fodder potatoes on a large scale, but this crop is now dissapearing; at present, only Eastern European countries grow potatoes for stock feed in large quantities. In Poland and Russia - the world's two largest potato producing countries - nearly two-thirds and one-half of the total crops is used for fodder, respectively.

Potato production for starch and alcohol is of limited importance in the world. Only in the Netherlands, where more than one-third of the total crop is grown for starch, are potatoes for starch production really important. Other countries where production for starch is of some importance are Poland, USSR, and Japan.

Human consumption: As is the case for potato utilization in general, reliable data on human consumption are not available. The only comparable international estimates are published by the FAO. However, research conducted by Poats in a number of countries indicates that FAO statistics may significantly underestimate actual levels of potato consumption in developing countries (Poats, 1982). Therefore, the reader is cautioned that our consumption estimates, based on FAO figures, should be considered as rough orders of magnitude, and not precise statistics. Eastern Europe has the highest per capita potato consumption level of any world region (Figure 5). With per capita consumption of 166 kg, Poland has the highest level of any country. In Western Europe it appears that per capita potato consumption has stabilized at about 90 kg per capita. In the USA, where per capita consumption is still considerably lower than in Western Europe, it is increasing gradually over time.

Annual potato consumption per capita appears to be more or less stable in Latin America, while in other developing regions, especially Asia, per capita consumption is increasing (Figure 6). Per capita potato consumption in Latin America and the Near East is about 20-25 kg; in Africa and the Far East it is only about 6 kg.

Farm-level and retail prices: Data on farm-level and retail prices for potatoes, wheat, and rice on a regional basis are summarized. This analysis indicates that at both the farm and retail levels the absolute price of potatoes is higher in developing countries than in Western Europe, while the prices of bread and rice are lower (Table 14). Tables 15 and 16 present estimates of consumer-level costs of food nutrients provided by these foods, based on retail prices published by the ILO (1978) and food composition tables published by the USDA (1975). Table 17 presents data from another source on relative retail costs of energy and protein derived from potatoes, wheat flour, and rice in several countries. Assuming that 100% of each foodstuff is consumed, it is concluded that on average in developing countries energy and protein derived from bread and rice cost considerably less than energy and protein derived from potatoes. (Inclusion of such factors as inedible portion in our calculations would not change the general conclusion).

Although in countries with market economies the consumer price of ware potatoes at any given time is determined by momentary supply and demand conditions, the average consumer price level over longer periods is determined by costs of production, storage, and distribution. It is often argued that retail potato prices are high in developing countries because of high marketing costs and profits. Available data do not support this view. Farmers receive a considerably higher proportion of the retail price in developing countries than in developed countries (Table 18). Moreover, data presented in

Table 10. Cost structure for the potato crop in selected countries of South America[1].

	Peru[1]		Ecuador[2] highlands	Colombia[3] highlands	Chile[4]	
	Coast	Highlands			South	Central
Structure (%)						
Labor	17	16	37	34	15	24
Equipment	11	10	7	6	21	25
Seed	38	29	27	24	33	37
Fertilizers						
Chemical	12	14	19	22	31	12
Organic	8	14	-	-	-	-
Pesticides	14	17	10	14	-	2
Total	100	100	100	100	100	100
Total in 1980 US$	1,653	1,591	1,496	1,240	2,357	1,444
Yield (t/ha)	18	10	-	18-25	24	15

[1]From International Potato Center estimates; [2]Solis, 1978; [3]Flores et al., 1979; [4]Fu, 1979.

Table 11. Cost structure for the potato crop in selected countries of Asia.

	Bangladesh[1]	India[2]	Korea[3]	Pakistan[4]	Philippines[5]
Structure (%)					
Labor	20	18	38	18	16
Equipment	15	6	3	6	2
Seed	36	45	32	53	55
Fertilizers					
Chemical	26	18	26	7	8
Organic	-	9	-	13	9
Pesticides	1	4	1	3	10
Total	100	100	100	100	100
Total in 1980 US$	2,589	-	-	1,352	1,893
Yield (t/ha)	-	-	-	-	20

[1]From Elias, 1980; [2]Menegay, 1975; [3]Anonymous, 1977; [4]Wustman and Mahfooz, 1980; [5]PCARR, 1979.

Table 12. Cost structure for the potato crop in selected countries of Africa Central America, USA and the Netherlands.

	Kenya[1]	Rwanda[2]	Guatemala[3]	Mexico[4]	USA[5]	Netherlands[6]
Structure (%)						
Labor	54	52	10	18	8	16
Equipment	6	-	5	14	39	24
Seed	21	38	53	47	19	21
Fertilizers						
Chemical	4	-	17	16	23	11
Organic	8	-	-	-	-	-
Pesticides	7	-	15	5	11	8
Fixed costs	-	-	-	-	-	20
Total	100	100	100	100	100	100
Total in 1980 US$	637	306	1,453	1,079	1,777	2,500
Yield (t/ha)	-	6	-	-	38	40

[1]From Durr and Lorenyl, 1980; [2]Durr, 1980; [3]Anonymous, 1975; [4]Ferroni, 1981; [5]Grieg, 1975; [6]Anonymous, 1981.

Table 13. Utilization of the world potato crop[1].

Use	Quantity (10^3 t)	%
Human consumption	126	45
Stock feed	88	31
Starch	6	2
Seed	39	14

[1]From International Potato Center, 1982.

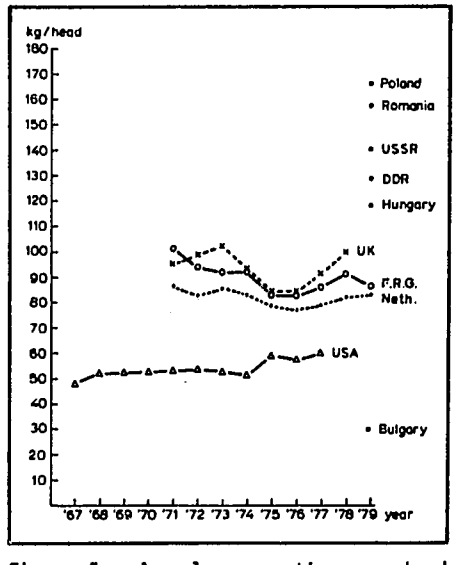
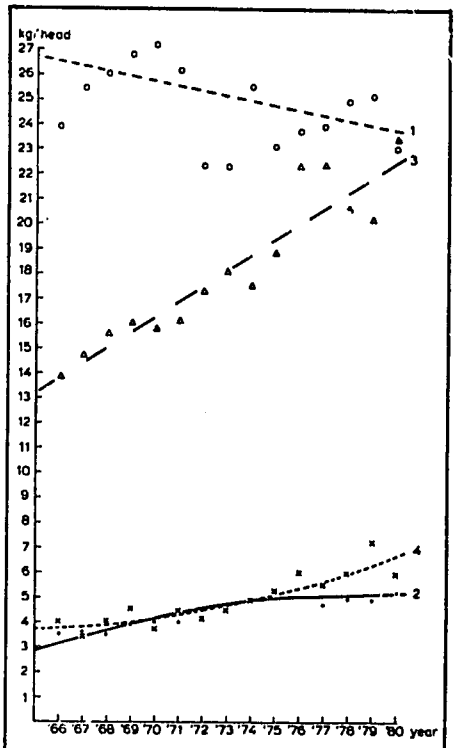


Figure 5. Annual consumption per head in USA, Netherlands, Federal Republic of Germany and U.K. (Sources: USA - Thornton and Sieczka, 1980; Western Europe - Produktschap voor Aardappelen; Eastern Europe - Dr. Kapsa).

Table 19 indicate that while the marketing margin is lower, the production cost per unit edible energy is higher for potatoes in developing countries than in an industrialized country (the Netherlands). Hence, the high consumer price of potatoes in the developing countries is due not to high distribution costs, but to high production costs.

Price and income elasticities: It is often assumed that potato consumption is insensitive to changes in prices and income levels. To study the relationship between potato prices, income and consumption, regression analysis was applied to estimates of potato consumption (FAO, 1980), incomes (ILO, 1978) and potato prices (ILO, 1978) for 51 countries. Based on previous work, (FAO, 1972; Quintanilla, 1978; Amat y Leon and Curonisy, 1981) the following functional form was postulated: $C = aI^b P^c$ (1)
where: C = per capita consumption (kg), I = hourly wage rate of bricklayer (US$), P = retail potato price (US$), a = constant term, b = income elasticity of demand, c = price elasticity of demand. Formula (1) can be rewritten in logarithmic form, allowing coefficients a, b, and c to be estimated using ordinary least squares (t values are given in parentheses).

$$\log C = -0.205 + \underset{(8.62)}{0.965} \log I - \underset{(8.25)}{2.209} \log P \quad (2)$$



1) $\hat{y} = 25.7 - 0.13x$
$r = 0.39$

2) $\hat{y} = 2.91 + 0.3084x - 0.0106x^2$
$r = 0.88$

3) $\hat{y} = 13.2 + 0.62x$
$r = 0.94$

4) $\hat{y} = 3.68 + 0.0407x + 0.0105x^2$
$r = 0.91$

Figure 6. Development of the annual consumption per head in developing countries with market economies in (1) Latin America, (2) Africa, (3) Near East, and (4) Far East (assumed that rate of consumption is production per head - 10% - 1.5 tonnes for seed) (Based on the production and population in 1978-1980, FAO Production Yearbook).

Table 14. Average retail prices for potato, bread, and rice in different parts of the world 1977 (US$/100 kg)1/.

Production area and (number of countries)	Potato	Bread	Rice
Developed countries			
USA	40	82	79
Western Europe (14)	27	93	112
Eastern Europe (4)	39	75	120
Developing market economies			
Africa (20)	53	55	71
Latin America (13)	40	70	56
Near East (4)	44	31	87
Far East (9)	28	55	34

1/ From ILO, 1978; United Nations, 1980; IMF, 1980.

Table 15. Average cost (US$) of 10^6 kJ food energy from potato, bread and rice 1977 1/.

Area and (number of countries)	Potato	Bread	Rice
Developed economies			
USA	129	90	56
Western Europe (14)	87	103	79
Eastern Europe (4)	126	83	85
Developing economies			
Africa (20)	171	61	50
Latin America (13)	129	77	40
Near East (4)	142	34	61
Far East (9)	90	61	24

1/ For energy values see Table 7, and also Table 14.

Table 16. Average cost (US$) of 1 kg protein from potato, bread and rice 1977 1/.

Area and (number of countries)	Potato	Bread	Rice
Developed economies			
USA	20	10	11
Western Europe (14)	14	12	16
Eastern Europe (4)	20	9	17
Developing economies			
Africa (20)	27	7	10
Latin America (13)	20	9	8
Near East (4)	22	4	12
Far East (9)	24	7	5

1/ For protein values see Table 7 and also Table 14.

Table 18. Farm price as percent of retail price in selected regions and countries 1/.

Area and (number of countries	Farm price as % of retail price
Africa (10)	52
Latin America (6)	69
Near East (2)	54
Far East (7)	61
USA	22
Netherlands	33

1/ From ILO, 1978; FAO, unpublished.

Table 19. Production cost, consumer price, and marketing margin for 10^6 kJ edible energy from potatoes, wheat and rice 1/.

Locations and cost allocation	Potatoes	Wheat/ bread	Sugar
Netherlands			
1. Consumer price (US$)	81	116	51
2. Farm cost (US$)	18	17	14
3. Marketing margin (1-2)	63	99	37
3 as % of 1	78	85	72
Developing countries			
1. Consumer price (US$)	97	47	37
2. Farm cost (US$)	47	14	18
3. Marketing margin (1-2)	50	33	19
3 as % of 1	52	70	51

1/ From Tables 7 and 8.

Table 17. Relative retail prices of ware potatoes, wheat flour and rice in terms of energy and protein1/.

Countries (city)	Date	Potatoes	Wheat flour		Rice	
			Energy2/	Protein2/	Energy	Protein
Congo	1977-79	100	32	26	15	20
India (Bombay-Calcutta)	1973-77	100	21	17	24	31
Irak (Bagdad)	1973-76	100	15	12	41	54
Israel	1975-78	100	21	17	40	52
Jamaica (Kingston)	1973-77	100	16	14	20	25
Jemen (Aden)	1974-75	100	15	15	20	25
Jordan	1974-77	100	13	13	36	46
Kenya (Nairobi)	1976-78	100	46	38	31	40
Pakistan (Lahore)	1974-80	100	17	15	30	39

1/ Data provided by Central Bureau voor Statistiek, the Netherlands.
2/ For energy and protein values see Table 7.

Equation (2), which explained 75% of the variation in per capita potato consumption among countries, indicates that potato consumption is highly responsive to changes in income and price. The estimated income elasticity of 0.965 means that as incomes increase by 1% potato consumption can be expected to increase by about the same proportion; the estimated price elasticity of -2.208 means that for each 1% decrease in potato prices, consumption can be expected to increase by about 2%. It should be noted that the absolute values of these elasticities are much greater than those published for most developed countries, and those assumed to prevail in most developing countries (FAO, 1972; IFPRI, 1977).

Future development and its limiting factors

Ethanol as energy

Studies on biomass production as a source of energy have been made in many countries, and potato has been mentioned as a potential energy crop. Is the potato a promising crop for this use? To answer this question the following aspects are relevant: (1) cost of production and processing of the biomass, (2) the energy output/input ratio, and (3) energy or ethanol production per ha.

Table 20. Cost of biomass production for energy for Dutch conditions 1/.

Crop	Energy production (GJ/ha)	Energy used for production (GJ/ha)	Net energy production crop (GJ/ha)	Cost per unit biomass energy (guilders per GJ)
Sugar-beets	180	25	155	29.3
Potatoes	141	55	86	52.0
Wheat	94	28	66	49.0
Wood for energy production	288	18	270	9.3

1/ From Brand, 1979.

At present in Western Europe fodder and sugar beets can produce more ethanol per ha than potatoes (Dambroth and Bramm, 1980; Brand, 1979). Also the cost of producing the biomass in sugar beets is considerably cheaper than in potatoes (Table 20). In terms of both energy yield and production cost per unit energy, wood is much more promising than field crops. Despite this, ethanol produced from wood is more expensive than other sources in the Netherlands. Only where wood is produced in land with no alternative crop use is this source of energy production feasible at present.

Extensive studies in the USA have been made comparing the energy output/input ratio for various crops. Table 21, showing the overall energy balance for production of ethanol from various biomass, is the result of such a study (Krochta, 1980). In most crops the overall energy balance is negative or near break-even. Only processes using crop residues have a clear positive balance.

A small positive balance can be obtained with potatoes if the output/input energy ratio for crop production is 19.10^3 Btu/gal ethanol ((84 x 1,054 kJ) + (19 x 1,054 kJ)) that is a ratio of about 4.4. That is an extremely high ratio. A quite more normal ratio is 2.5 (Pimentel, 1975; Van der Zaag, 1978; Brand, 1979). Waelti (1981) calculated a total output/input energy ratio of 1.35 if by-product of the ethanol production is not dried. However, his calculation is based on a yield of 124 tonnes per ha. If yield were reduced from 124 to 99 tonnes per ha the energy balance would be near break-even. From these few examples we conclude that the potato is not likely to be used for ethanol production as a source of energy in the foreseeable future.

Table 21. Overall energy balance for production of fuel-grade anhydrous ethanol from various biomass 1/.

	Energy							
	Corn	Sorghum	Wheat	Potatoes	Sugar-beets	Sugar-cane	Molasses	Residues
Inputs	1.000 Btu/gal. ethanol							
Crop production	33-65	38-76	29-64	19-69	21-41	11-31	33-65	0
Feedstock preparation	9	9	9	9	9	9	0	18-36
Fermentation	0	0	0	0	0	0	0	0
Distillation	30	30	30	30	30	30	30	60 2/
By-product recovery	30	30	37	12	39	0	0	15
Miscellaneous	15	15	15	15	15	15	15	30
Electricity	10	10	10	10	10	10	10	20
Total	127-159	132-170	130-165	95-145	124-144	75-95	88-120	143-161
Outputs								
Ethanol	84	84	84	84	84	84	84	84
By-products	50	50	62	20	65	0	0	168 3/
Total	134	134	146	104	149	84	84	252
Outputs/inputs	0.8-1.1	0.8-1.0	0.9-1.1	0.7-1.1	1.0-1.2	0.9-1.1	0.7-0.9	1.6-1.8

1/ From Krochta, 1980.

2/ Distillation of ethanol and pentose-conversion product.

3/ Includes pentose-conversion and lignin products.

Starch

At the Triennal Conference of the European Association for Potato Research in 1975, Van der Zaag (1976) discussed the future possibilities of potato production for starch. Comparing potatoes with maize, he concluded that production of potatoes for starch would be competitive with maize production only if maize prices were above D.fl. 30-35 per 100 kg.

The calculation has been updated. It is now assumed that to produce 1 kg starch (dry matter content 88%) about 5.5 kg potatoes (22% D.M.) or about 1.55 kg maize are needed. It is also assumed that the processing cost of 1 kg potato starch (disregarding the price of raw material and possible returns from by-products) is D.fl. 0.25 higher than the processing cost of 1 kg maize starch. The total production cost of 1 kg starch is then:

$5.50\ y + (p + 0.25)$ for potato starch

$1.55\ x + p$ for maize starch

where: y = price of potatoes per kg, x = price of maize per kg, p = processing cost per kg.

Hence, for production of 1 kg starch of equal cost from potatoes and maize:

$$5.50\ y + (p + 0.25) = 1.55x + p \qquad (3)$$

$$y = 0.28x - 0.045$$

Based on the price relationship of equation (3), average yields for maize and potatoes in the Netherlands (Table 22), and revised gross margin calculations for these two crops (Appendices 1 and 3), the gross margins per ha at 5, 7, and 8.5 t/ha yield for maize and 30, 40 and 50 t/ha yield for potatoes have been calculated for a range of prices (Figure 7). From Figure 7 it can be concluded that in starch production, even at a maize price of D.fl. 0.70 per kg, a potato crop yielding 40 t/ha can not compete with a maize crop yielding 7 t/ha.

In the Common Market, where the maize price is about D.fl. 0.55 per kg, production of starch from potatoes is competitive with maize only if the potato price is below about D.fl. 0.11 per kg. But at this low price potatoes are less profitable for farmers than maize. Hence, we concluded that there is no reason to expect an increase in potato production for starch in countries where maize can be imported at a world market price of below D.fl. 0.70 (US$0.26) per kg.

Table 22. Average and relative yield of potatoes, barley and maize 1978-1980 1/.

	Potatoes	Barley	Maize
Average yield (t/ha)			
North America	25.4	2.48	6.27
Western Europe	22.5	3.53	4.87
Netherlands	37.6	4.80	6.80
Relative yield (potato = 100)			
North America	100	10	25
Western Europe	100	16	22
Netherlands	100	11	16

1/ FAO. Production Yearbook 1981.

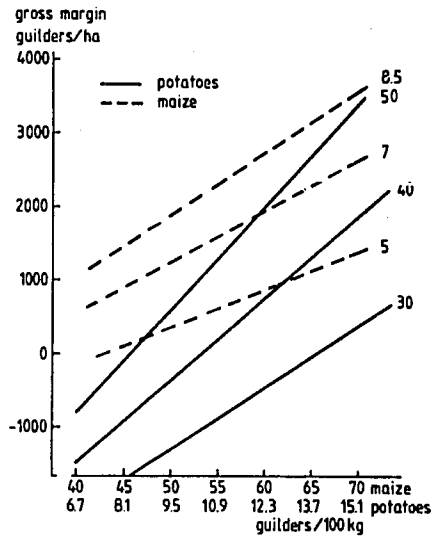


Figure 7. Estimated relationship between prices of maize and potatoes for starch production and the gross margins per ha at 5,7 and 8.5 tonnes yield of maize and 30, 40 and 50 tonnes yield for potatoes (For price relation maize - potatoes see text and for gross margin calculations Appendices 1 and 3).

Stock feed

Van der Zaag (1976) also discussed possible future use of potatoes for stock feed. Comparing potatoes with maize and barley, he came to the conclusion that production of potatoes for stock feed had a future only if the barley and maize prices rise above D.fl. 45.- and 60.- per 100 kgs, respectively. Despite a recent price increase in barley price to D.fl. 50.- potato production for stock feed has almost disappeared in Western Europe. Nevertheless, it persists in Eastern European countries with centrally planned economies. This may reflect a relative production advantage for potatoes in this part of the world.

Based on the situation in 1982 a revised comparison has been made. It is assumed that 4 kg fresh potatoes are required to produce 1 kg dehydrated product. It is also assumed that the relative food values per kg of maize, barley, and dehydrated potatoes are 0.80, 0.70 and 0.75, respectively. Then for 1 kg of stock feed of equal cost and food value, the following relationship must be hold:

$$\frac{4\,y}{0.75} = \frac{x}{0.8} = \frac{z}{0.7} \qquad (4)$$

where: x = price of maize per kg, y = price of fresh potatoes per kg, z = price of barley.

For a farm with good soil, where all three crops grow well, the gross margins per ha have been calculated based on the situation in the Netherlands (Appendices 1, 2 and 3). Figures 8 and 9 show gross margins per ha for maize, barley, and potatoes for a range of prices, respecting the price relationship of equation (4). With yields of 40 t/ha for potatoes, 5 t/ha for barley, and 7 t/ha for maize, potatoes for stock feed are competitive with these crops only at prices above D.fl. 0.60 per kg.

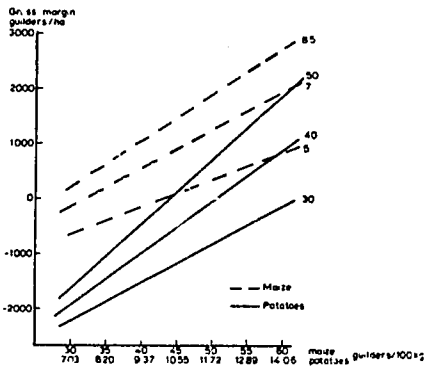


Figure 8. Estimated relationship between prices of maize and feed potatoes and the gross margins per ha at 5,7 and 8.5 tonnes yield for maize and 30, 40 and 50 tonnes yield for potatoes (For price relation maize-potatoes see text and for gross margin calculations Appendices 1 and 3).

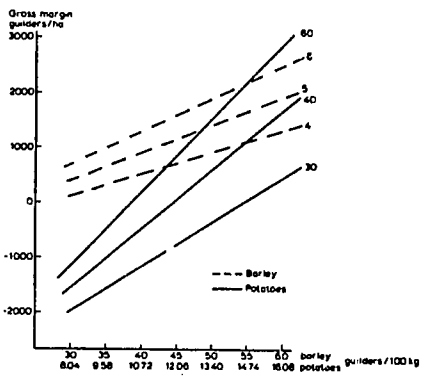


Figure 9. Estimated relationship between prices of barley and feed potatoes and the gross margins per ha at 4,5 and 6 tonnes yield for barley and 30, 40 and 50 tonnes yield for potatoes (For price relationship barley-potatoes see text and for gross margin calculations Appendices 2 and 3).

In the Common Market, where barley and maize prices are now about D.fl. 0.50 and 0.55 per kg, respectively, potato production for stock feed is not profitable. In countries where barley, maize, and other stock feeds are cheaper than in the Common Market (generally the case on the world market), potato production for fodder is even less profitable, nor is it expected to become so in the foreseeable future. No prediction can be made for countries with centrally planned economies. There are no indications that potato production for stock feed will disappear in Eastern Europe.

Human consumption

Temperate zone: As already noted, it appears that in industrialized countries

Appendix 1

Example of gross margin estimation for maize (main operations on the crop done by contractor, based on Anonymous, 1981).

Yield: 7000 kg at D.fl. 0.30/kg		D.fl. 2100.-
Material:		
seed	D.fl. 150.-	
NPK	800.-	
pesticides	50.-	
herbicides	50.-	
		D.fl. 1050.-
Insurance and interest		50.-
Contractors:		
sowing	D.fl. 150.-	
spraying	100.-	
harvest	400.-	
chopping straws	100.-	
drying	400.-	
		D.fl. 1150.-
		D.fl. 2250.-
Gross margin/ha		- D.fl. 150.-

Appendix 2

Example of gross margin estimation for barley (main operations on the crop done by contractor, based on Anonymous, 1981).

Yield: 5000 kg at D.fl. 0.30/kg		D.fl. 1500.-
straw		400.-
		D.fl. 1900.-
Material:		
seed	D.fl. 125.-	
NPK	500.-	
pesticides	50.-	
herbicides	50.-	
		D.fl. 725.-
Insurance and interest		50.-
Contractor:		
spraying	D.fl. 100.-	
harvest	350.-	
baling straw	150.-	
drying	100.-	
		D.fl. 700.-
		D.fl. 1475.-
Gross margin/ha		D.fl. 425.-

Appendix 3

Example of gross margin estimation for potatoes for stock feed and for starch production (main operations on the crop done by contractor, based on Anonymous, 1981).

Yield: 40000 kg at D.fl. 0.0804/kg		D.fl. 3216.-
Material:		
seed	D.fl. 700.-	
NPK	850.-	
fungicides	100.-	
herbicides	100.-	
		D.fl. 1750.-
Insurance and interest		150.-
Contractor:		
planting	D.fl. 150.-	
spraying	200.-	
harvest and transport	900.-	
dehydration at D.fl. 4/100 kg[1/]	1600.-	
		D.fl. 2850.-
		D.fl. 4750.-
Gross margin/ha		- D.fl. 1534.-

1/ only for stock feed, Anon. 1980.

with market economies per capita potato consumption has more or less stabilized. The gradual decline in consumption of fresh potatoes is offset by increased consumption of processed potatoes. Assuming constant consumption per head, constant population, and about 1% annual yield increase, the area under ware potatoes may be expected to decrease by about 1% per year in the coming years. That would mean that by the year 2,000, the area under ware potatoes may fall by about 20% in North America and Western Europe.

For countries with centrally planned economies it is difficult to predict future production of ware potatoes, although there seems to be no reason for expecting a drastic change.

Tropical and sub-tropical zone: The potential for increasing potato consumption in the tropics has been discussed at this conference by Poats (1982). In the present paper only a few remarks will be made, relating to findings of Poats (1981; 1982).

In many developing countries a key reason for low potato consumption is the high price of ware potatoes relative to the prices of other available foodstuffs. According to Poats' typology the potato can be considered a staple food where per capita consumption is in the range of 60-200 kg per year, a complementary vegetable where consumption is 15-50 kg per year, and a luxury vegetable where consumption is less than 10 kg per year.

We believe that the future of the potato crop in developing countries depends very much on the degree to which potato prices are reduced relative to other food prices. Given our findings on retail prices and consumption levels it seems reasonable to expect that as long as the potato price, expressed in food nutrients, remains 3 or more times the price of alternative food sources the potato will remain a luxury vegetable. This is presently the case in most lowland tropical areas. Where the price ratio is around 2 the potato may become a complementary vegetable, as it is shortly after harvest in several lowland sites growing potatoes in short, cool winter seasons or being supplied with potatoes grown in distant highland zones. And at price ratios below this level the potato may become a basic staple food. This is presently the case in the temperate zone and in tropical highland zones, in the Andes, Central and Eastern Africa, and scattered throughout Asia.

Discussion and preliminary conclusions

Potato prices are lower in Europe than in other regions of the world. Yet the analysis of this section indicates that the potato is not the most economical crop for ethanol production in Europe. Fodder beets and wood are superior alternatives with present technology and prices. However, not even these crops are competitive with conventional sources of energy at the present time. It is therefore, not expected that a demand for potatoes will arise from this ethanol production, except for processing waste tubers not suitable for consumption or seed or perhaps in years of large surplus.

Potatoes are not competitive with maize for starch production at present world market prices. Additionally, starch production from potatoes may be more sensitive to energy costs and costs required to prevent pollution than starch production from maize. It is, therefore, not likely that use of potatoes for starch production will increase. On the contrary, this use will probably decrease unless maize prices increase substantially.

The same applies for use of potatoes for stock feed. Only at high world market prices for barley and maize would potato production for stock feed be profitable in Western Europe. In most other parts of the world potatoes are an even more expensive source of livestock feed. It seems likely that in the near future potato production for stock feed will be restricted to temperate zone countries with centrally planned economies.

In Western Europe and North America annual per capita potato consumption has more or less stabilized. A small increase may be expected, if consumers are better informed about the nutritive value of potatoes and if consumer requirements regarding quality and processed forms are met. Despite a small projected increase in consumption, the area cropped with ware potatoes will probably decrease as yields increase.

In tropical and sub-tropical countries of Africa and Asia, per capita potato consumption is increasing rapidly. Is this trend likely to continue? Are there possibilities of accelerating this increase in consumption? And will it be possible to produce enough potatoes to fulfill the demand? As discussed by Poats and Castillo (1982) the rate of potato consumption depends on several factors. One key factor is the retail price of the potatoes relative to prices of other foodstuffs. In low income countries we feel that the scope for increased potato consumption is great, if potato prices can be reduced.

The potato's high energy and protein production per day and per ha make this crop attractive to poor farmers with little cropland. Due to its short vegetative cycle, the potato crop can fit into intensive rotations allowing small farmers to produce a large volume of highly nutritious food for home consumption and for market in a short time on a small land area. More potatoes could easily be produced in most developing countries with present technology and production capacity. But at what price? Needed is low-cost technology which allows farmers to produce more potatoes at a lower unit cost. We believe that the future of the potato crop in the tropics and sub-tropics will depend very much on the extent to which the price of ware potatoes can be reduced in relation to prices of other foodstuffs. If prices are reduced, consumption of ware potatoes will be greatly stimulated. This is important both for improving human nutrition and the welfare of small farmers.

Potential contribution of research to potato production and consumption in the tropics and sub-tropics

In the foregoing section we conclude that the future of the potato crop in the tropics and sub-tropics depends in large part on reduction of the retail potato price. In the present section we analyze the possibilities of reducing the major cost factors previously identified: seed, fertilization, and labor input. At the end we discuss briefly the possibilities of reducing production costs of other food crops, and draw some conclusions.

In principle, the cost per unit tuber weight can be reduced in two ways: by reducing production cost per ha while maintaining yield, and by increasing yield while maintaining production cost per ha.

Possibilities to Reduce Production Cost per Ha

From data presented in the foregoing section it can be concluded that in most developing countries the major cost factors are seed, fertilization, and labour.

Tuber seed: Three means of reducing seed costs per ha are (a) breeding varieties resistant to tuber-borne diseases, (b) setting up seed tuber multiplication programs which are adapted to local conditions, and (c) making use of true potato seed.

Breeding resistance to PLRV, PVY, and *Pseudomonas solanacearum* is important. Results obtained with breeding for resistance to tuber-borne diseases and viruses are promising, and by the year 2,000 resistant varieties may be available on a large scale.

Not many developing countries have good seed multiplication programmes. It seems to be much easier to produce a small quantity of high quality seed than to distribute to farmers a large quantity of seed of reasonable quality. We feel that too much emphasis has been placed on production of basic seed and not enough on simple multiplication of this basic seed and delivery of reasonably good seed to ware growers. Also, too many seed programmes are a copy of the programmes of industrialized countries, which are not adapted to developing country conditions (Monares, 1981a).

A general study of both technical and socioeconomic aspects of seed programmes in developing countries is needed. Such a study should start from the needs to ware growers and the demand for improved seed rather than from the technical aspects of producing basic seed, as in usually done.

Even if a good programme is established and ware growers can purchase good seed at a reasonable price, seed will remain an important cost factor. The following example illustrates this point: if the yield is 20 t/ha and the ware price is represented by the symbol p, total revenue/ha can be represented as 20 p. If net revenue is 10% of total revenue, then total cost is 0.9 x 20 p. If the cost of seed, including storage costs and losses, is twice the price of ware potatoes and the seed rate is 1.5 t/ha, seed cost can be expressed as 1.5 x 2 p. From this it follows that the share of seed cost in the total production cost is:

$$\frac{1.5 \times 2\ p}{0.9 \times 20\ p} = \frac{3\ p}{18\ p} = 17\%$$

Given realistic technical coefficients and price relationships, it can be concluded that it will be difficult to reduce the proportion of tuber seed in total production cost below this level.

True potato seed: Use of true potato seed (TPS) offers perhaps the greatest potential for reducing potato production costs per ha, where healthy seed is extremely costly. As discussed by Sadik (1982) and Monares *et al.* (1982), TPS can be used to

produce either ware potatoes or seed potatoes.

Use of TPS for ware production offers several potential advantages over use of conventional tuber seed, as in discussed by Sadik (1982). In this section we will restrict ourselves to a discussion of the possibility that use of TPS will reduce production cost per ha while maintaining yield, or will reduce production cost by more than enough to compensate for the reduction in yield.

To evaluate possible use of TPS for production of ware potatoes, we compare transplanted seedlings with available seed tubers. Where seed tubers are healthy and in good physiological conditions and the crop from these seed tubers makes full use of the available growing season, transplanted seedlings from TPS are likely to yield less than a crop from healthy seed tuber (usually about 3 weeks less tuber growth). Assuming that the tuber seed rate is 1.5 t/ha and that TPS results in a yield reduction of 4 t/ha, use of TPS will be profitable for farmers if healthy tuber seed costs about 3 or more times the price of ware potatoes. (This assumes that TPS is cheap and that other production costs are the same for both systems).

This example shows that if seed tubers are very costly, use of TPS for ware potato production can result in a reduction in production cost per ha which is more than proportional to the reduction in yield. In cases where available seed tubers are infected with viruses or are in poor physiological condition, use of TPS might even reduce production cost without reducing yield.

TPS can also be used in a seed production programme. In regions where healthy seed is very expensive, or unavailable, production of seed tubers from TPS may be a promising means of reducing production cost both per ha and per kg ware potatoes produced. While such seed may be expected to be less expensive than conventional seed, in market economies its price should not be expected to fall below the price of small ware potatoes at harvest time. The Peoples' Republic of China now uses TPS for producing seed tubers for several thousand ha of potatoes. CIP is now developing a prototype seed production system in which a large number of small seed tubers can be produced from TPS on small, protected plots in the off-season (Wiersema, 1982). More information on the Chinese experience and on the economics of alternative seed systems would be useful for guiding future research and development of TPS technology for developing country conditions.

Fertilization: Production of high, sustained potato yields require a high rate of nutrient supply. Furthermore, the potato crop is sensitive to the balance of N, P, and K supply. Holm (1981) found considerable differences between potato clones in nutrient-use efficiency; they differed in yield under low soil nitrogen levels, yield response to applied nitrogen, and nitrogen recovery by tubers. He believes that it is possible to develop varieties which utilize available mineral nutrients more efficiently. He did not mention which selection method should be applied. It may be more difficult to develop efficient and reliable selection methods than to develop such varieties. However, we feel that research which makes it possible to breed for nutrient-use efficient would be useful in the long run.

Some varieties are very sensitive to optimal rates of N, P, or K, responding strongly if the rates are slightly below or about optimal levels. Other varieties are not so sensitive, having a much wider range of optimal rate. Developing country growers who do not have a means of precisely determining optimal rates of NPK could greatly benefit from varieties with a wide range of optimal fertilizers rate. Use of such varieties could help reduce the cost of fertilizer per ha while increasing yield.

Labour and mechanization: At present, temperate-zone mechanized farms use only one-sixth to one-tenth the labour they needed for potato production a few decades ago. One ha ware potatoes can now be produced and stored with only about 20-30 manhours in the Netherlands. In most developing countries the potato is still a labour intensive crop; one ha potatoes often requires over 200 manhours. This intensive use of labour need not be a disadvantage. On the contrary, in labour surplus areas it can be viewed as an advantage (Swaminathan, 1978). Yields can sometimes be increased through partial mechanization of such operations as ploughing, seed bed preparation, and planting. In most cases, however, mechanization has little or no production advantage over careful handwork (Hayami and Ruttan, 1971). Hence, before advocating mechanization of potato cultivation in a region or country, all aspects should be considered carefully. Only in cases where there is a shortage or high cost of labour, will mechanization reduce production costs.

Possibilities to reduce the cost of production per kg output

Actual and potential yields: Average yield does not always give a reliable indication of the technological level of potato production in a particular region. The ratio of actual to attainable yields reflect this much better. Actual yield is here defined as the average yield of all potato crops in the region taking advantage of the whole growing period. Attainable yield is what the actual yield in a region would be if all growers applied the best available growing techniques which were economically justifiable under their farming conditions. Since it is difficult to estimate this for large areas, we introduce the concept potential yield, which is the yield from a crop that makes full use of the whole vegetative period and where daily tuber production has been optimal (optimal water and mineral supply, optimal size of foliage, and no diseases or pests). The determinants of potential yield are temperature, solar radiation, and length of vegetative period. Discussion of these concepts and estimates of potential yield for potato crops are found in Van der Zaag (1977), Van der Zaag and Burton (1978), and Van der Zaag and Wustman (1980).

Table 23 presents actual and potential yields in a number of countries. The reader is cautioned to realize that both the calculated potential yield and the estimated actual yield (done by specialists in the countries concerned) are no more than crude approximations of reality. The technological level of potato production can be classified as follows:

Ratio of actual yield: Potential yield	Technological level
>0.4	high
0.3-0.4	good
0.2-0.3	low
<0.2	very low

Table 23. Actual and potential yield of potatoes in selected countries and growing seasons.

Country	Growing season	Actual yield (t/ha)	Potential yield (t/ha)	Actual: potential yield
Washington (USA)	21/3 - 15/10	65	135	0.48
Netherlands	1/4 - 1/10	45	100	0.45
Egypt	1/1 - 1/5	20	55	0.36
	1/9 - 1/1	15	50	0.30
Algeria	1/12 - 1/4	15	45	0.33
	15/3 - 1/7	12	65	0.18
	1/8 - 1/12	8	55	0.15
Tunisia	15/2 - 1/6	15	65	0.23
Morocco	15/1 - 1/5	15	60	0.25
Pakistan	15/1 - 1/5	15	45	0.33

According to this rather arbitrary classification, the technological level of potato production is good in countries such as Egypt and Pakistan an also in the Algerian early potato crop (primeurs) despite the fact that their actual yields are low in relation to those obtained in Washington State (SUA), and in the Netherlands. In many tropical and sub-tropical countries the actual yield is often 10 t/ha or less. Although the actual yield is somewhat higher than the average yield in a region or country, it may be supposed that in most of these countries the ratio actual: potential yield is usually below 0.3 and often even below 0.2. In this respect it is as well to realize that in several parts of Europe this ratio is also about 0.3 and sometimes even lower. From this point of view the technological level in several tropical and sub-tropical countries is not as poor as often assumed.

Nevertheless, in many developing areas it may be possible to double yields through correct application of good production techniques and existing varieties. A doubling of yields in all developing countries would result in an average yield of about 20 t/ha. Based on the data in Table 23, and considering the short growing period in many tropical and sub-tropical areas, it may be assumed that the average potential yield for developing countries is 50-60 t/ha. Hence, if actual yield reach 20 t/ha the ratio of actual to potential yield would be about 0.3 - similar to the ratio now existing in Western Europe.

The rapid increase in potato yields in Latin America and Asia over the last 15 years indicates that progress can be made, through application of technology. The question is how this process can be accelerated. CIP could follow 2 complementary strategies:

Working in a few countries in close collaboration with local authorities, to identify and resolve yield constraints

using existing production principles. In addition to improving productivity in a short time such activity gives valuable information about yield constraints and factors limiting use of new technologies by farmers.

Breeding varieties which are less sensitive to unfavourable growing conditions and make new knowledge available so that growers are less affected by unfavourable growing conditions and by incorrectly applied techniques.

As seed quality is an important yield determining factor, it will be discussed before the other research priorities.

Tuber seed: Possibilities of reducing seed cost per ha have been discussed. Reduction of seed cost is, of course, favorable as long as it does not reduce seed quality and yield below a critical level. The relationship between seed price and quality should always be kept in mind. To demonstrate the importance of this relationship an example is presented. Virus disease is used as the "quality" variable, because more information is available on yield reduction from virus diseases than from changes in physiological age or other quality aspects (except size grading). In many cases physiological condition of the seed is a more important quality factor of tuber seed than level of virus infection.

Yield reduction caused by leafroll virus and virus Y can be calculated by means of a formula (Reestman, 1970). Using another formula the price relationship between seed with different levels of infection can be calculated. Using these two formulae we estimate the level of price above which it is more profitable for the farmer to purchase healthy seed than to plant his own degenerated seed, 100% infected with PLRV, PVY, and showing strong reduction of foliage growth. This is called the break-even point (Table 24). For details of the method of calculation the reader is referred to Van der Zaag (1982b).

In many regions seed is heavily infected with viruses. Where almost all plants are infected with PLRV or PVY the break-even point of healthy seed is about 10 x price of ware potatoes. To obtain a good view of the effect of healthy seed of reasonable price on yield and production cost per unit the following example is given. In this example the following assumptions are made about the original situation: yield = 10 t/ha, seed rate = 1.8 t/ha, net return = 10% gross return, and the price of both ware potatoes and common seed = p/t. Given these assumptions, the proportional cost of common seed in the original production cost/ha is (1.8 x p) / (0.9 x 10 p) = 20%. The original cost per ton of ware potatoes produces is (9 p) / (10 t) = 0.9 p/t.

In the new situation as a result of using healthy seed, it is assumed that yield = 25 t/ha, and the price of healthy seed = 3 p/t. All other factors are assumed to remain the same. Hence, the proportion of healthy seed in the new production cost/ha is much higher than in the original situation is (1.8 x 3 p) / (0.9 x 10 p + 1.8 x 2 p) = 43%. And the new cost of ware potatoes produced is (12.6 p) / (25 t) = 0.5 p/t.

This example illustrates how use of healthy seed costing 3 times as much as degenerated seed can increase the proportion of seed cost in total production cost (from 20% to 40%) but decrease the cost of producing potatoes (from 0.9 p/t to 0.5 p/t). In this example, the producer using healthy seed could sell his ware crop at a price 40% lower than the original price of the grower using degenerated seed and still have 2.5 times more profit per ha.

Table 24. Economically justifiable break-even point between the price of seed virtually free of virus compared with farmers' own seed saved from the ware crop 1/ 2/.

% virus infection of farmers' own save seed	Yield reduction when all plants are infected with leafroll virus or virus Y			
	50%		75%	
	one generation 3/	two generations 4/	one generation	two generations
0-5	1 x	1 x	1 x	1 x
25	2 x	4 x	3 x	6 x
50	4 x	8 x	5 x	11 x
75	6 x	10 x	8 x	14 x
100	8 x	12 x	11 x	18 x

1/ From Van der Zaag, 1982b.

2/ A seed price expressed as a multiple of the ware price. In all other respects the purchased healthy seed is assumed equivalent to the farmers' own saved seed. A yield of 25 t/ha and a seed rate of 1.8 t/ha are also assumed. If the yield level from healthy seed is 15 t/ha the seed prices mentioned should be reduced by about 1/3. If the seed rate is 1.2 t/ha the seed prices mentioned should be increased by about 1/3.

3/ One generation - the health standard of the progeny of the seed has not been incorporated.

4/ Two generations - the health standard of the progeny of the seed has been incorporated for the following generation.

True seed: The potential contribution of TPS to reducing production cost per ha has been discussed. The present section explores the potential to reduce production costs per kg output, by means of a yield increase. Such a yield increase may be expected where the health standard of available seed tubers is poor or the seed tubers are not in the correct physiological stage.

In regions where seed tubers are severely infected with PLRV, PVY, fungi or bacteria and the crop from TPS can be kept free from early infections, the yield of a crop from TPS may be considerably higher than the yield of a crop grown from heavily infected seed tubers. In such cases, use of TPS directly for ware potato production might considerably reduce the high production cost per kg tubers produced.

In areas where seed tubers produced from TPS can be kept reasonably healthy, use of these seed tubers may be more economical than using TPS directly for ware potato production. In such cases, TPS can play an important role in a seed potato programme reducing production cost per kg tubers produced.

We conclude that in areas with extremely low yields caused by very poor seed, use of TPS for ware production or to produce healthy seed potatoes may reduce the extremely high production cost per kg potato produced. On the other hand, use of TPS may no increase yields or be profitable in areas where good seed is already available at reasonable price.

Tolerances to drought, heat, frost, and salt:

Drought. Compared to other crops the potato is very sensitive to water stress. For optimal production, potatoes should be irrigated more frequently than other crops such as wheat, cotton, and tomatoes (Van Loon, 1981). It is generally accepted that in most potato producing countries water supply to the crop is one of the major factors limiting yield. In regions where irrigation is needed, the frequency, quantity and intensity or irrigation requires great care. Only in areas with a high production level can these requirements be met.

In areas where the crop can not be irrigated, the distribution patterns of rainfall is seldom optimal for crop production. In such situations the importance of a large amount of soil moisture is more important then where water can be regularly supplied by irrigation.

Three aspects of breeding for tolerance to drought should be considered: (a) the transpiration coefficient, (b) effect of short stress period on yield and quality, and (c) survival of plants after long stress periods.

In countries where water is scarce, varieties which produce more tuber dry matter with the same amount of water are needed. In different experiments Bodlaender (1982) found a considerable difference in water use per unit dry matter produced between the drought sensitive variety Saturna and the less sensitive variety Bintje. This finding indicates that differences in transpiration coefficient between varieties exists. Dwell et al. (1981) concluded that plants of a variety Russet Burbank may have excessive stomatal water loss, and that stomatal conductance could perhaps be reduced under field conditions without reducing photosynthesis.

Most important for developing countries are varieties which can easily stand short period of water stress. In areas with sophisticated irrigation systems, varieties are preferred which do not reduce the rate of photosynthesis immediately when some stress occurs. The variety Désirée is such an "optimistic" variety (Levi, 1982). However, in most areas with rainfed potatoes, more "pessimistic" varieties are preferred - varieties which close their stomata soon after some stress occurs (e.g., variety Up-to-Date). Although production is reduced during such stress periods, production is optimal when water is again available. For most developing country conditions "pessimistic" varieties have advantages over "optimistic" ones. In areas with very uneven rainfall distributions very "pessimistic" plants are needed, as they can survive long stress periods. Van der Wal (1982) found considerable varietal differences in potential of recovery after severe stress periods under glasshouse conditions.

Heat. High temperature can have a strong effect on production via (1) change in the distribution pattern of the

assimilates over the various parts of the plants and (2) reduced photosynthesis and increased respiration. In many tropical or sub-tropical countries potatoes are grown in cool seasons (spring or autumm). In such cases, temperature is high at the beginning or end of the vegetative period. Heat tolerance varieties may show a more rapid start at the beginning or a less reduction in tuber growth at the end. This, in combination with a longer vegetative period, could mean a considerable increase in yield.

Frost. In several sub-tropical countries, or at high altitudes in the tropics, frost may shorten the vegetative period. Frost tolerance would increase yield potential in such countries. Work done at CIP in this respect is promising and should be continued.

Salt. In most countries irrigation water and soils are not salty. There are, however, countries where salt is a problem, and as the potato plant is very sensitive to salt, potato production cannot develop very well under such conditions. Little information is available on varietal reaction to salt. Although this problem is of only regional importance, research on tolerance to salt should be stimulated.

Resistance to diseases and pests: Breeding for resistance to important diseases and pests has received so much attention from the beginning at CIP that possibilities of breeding varieties will not be discussed here. Therefore, we will confine ourselves to the remark that by the year 2,000 varieties with reasonable resistance to the most important virus diseases, late blight, and Pseudomonas solanacearum can be available. This is extremely important for reducing production cost, both per ha and per kg output.

Regulation of crop growth: The effect of growth regulators on haulm growth and tuber production is a difficult topic, but needs to be mentioned in our discussion of research for the potato in the year 2,000.

Day length and day and night temperature can strongly affect the balance of haulm and tuber yield, especially in tropical and sub-tropical countries, where length of the vegetative period is often restricted by these factors. Breeding varieties that are neutral or tolerant to these factors is important.

What are the possibilities of manipulating the crop with growth regulators?. After the optimistic views some decades ago about use of growth regulators in the potato crop, several physiologists are now pessimistic. The effect of growth regulators on plant development at different day and night temperatures is shown in Figure 10. It is suggested that both haulm growth and tuber initiation are influenced by a common hormonal control, and that temperature exerts its influence by altering the balance between the levels of endogenous gibberlins and inhibitors (Menzel, 1980). It is still not possible to successfully apply growth regulators in the potato crop on a large scale. At this moment farmers have only the tools of nitrogen application and irrigation to regulate, to some extent, the balance of haulm and tuber growth. Better tools would be of a great help for them to bridge the gap between the actual and potential yield. In the future, physiologists need to develop better methods for potato growers, especially in the tropics and sub-tropics, to regulate crop growth.

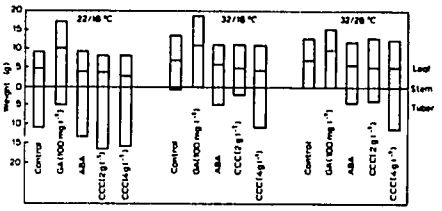


Figure 10. Effect of growth regulators on mean dry weight of leaves, stems and tubers (Menzel, 1980).

Possibilities of reducing storage costs for ware potatoes

In many developing countries facilities for storing ware potatoes for a reasonable long time are inadequate. Prices fall sharply at harvest time and rise again in periods of scarcity. Figure 11 shows this typical seasonal pattern for the wholesale market in Nairobi. In other areas, e.g., parts of China and Bangladesh, potato prices rise steeply and then, when supplies are exhausted, they are unavailable on the market for several months each year. For this reason, increases in potato consumption in developing countries depends both on reduction of prices to consumers and on making potatoes available to consumers year around. If production costs are reduced and potato production expands, limited storage capacity, losses and high storage costs may still limit potato availability and consumption. Therefore, it is essential that techniques be developed and introduced to store ware potatoes as effectively and cheaply as possible. Simple stores in which ware potatoes could be kept well for 20 weeks could help dampen price fluctuations considerably.

Promising work has been done by CIP and others to develop simple potato stores, especially for higher altitudes. Local testing, adaptation, and introduction of these systems into the various countries should be stimulated. In many areas tubers must be stored in periods when maximum and minimum temperatures are above 30° and 20°C, respectively. With existing varieties, refrigerated stores are needed for such conditions. More work should be done to develop cheaper stores for these areas, using local material and simple cooling units.

It is also important to breed varieties which can be stored well at high temperatures. More information is needed on the various aspects of keeping quality and its improvement through breeding. Finally, development of simple techniques to transform tubers into more easily stored products may be important for future expansion of the crop. Possibilities of developing such techniques are discussed by Burton and Booth (1982).

Given the important effect of seed quality on yields and the difficult conditions for tuber seed storage in many developing countries, particular attention needs to be given to improving seed storage technology. CIP work in this area shows how known principles can be effectively used to improve seed storage (Rhoades and Booth, 1982).

Discussion and conclusions

Future expansion of the potato crop in the tropics and sub-tropics depends in large part on reducing the price of ware potatoes, which, in turn depends largely on reducing production cost per kg output. Before drawing the conclusion from this discussion two additional aspects will be mentioned.

As many authorities have noted, many developing countries have little additional land to bring under cultivation. Hence, as population expands and man/land ratios increase, productivity of land now under cultivation must be increased. Crops that produce much energy and protein per unit time and area, such as the potato, will become increasingly attractive. Although we emphasize in this paper the importance of reducing production costs we should not forget that this should not be at the ex-

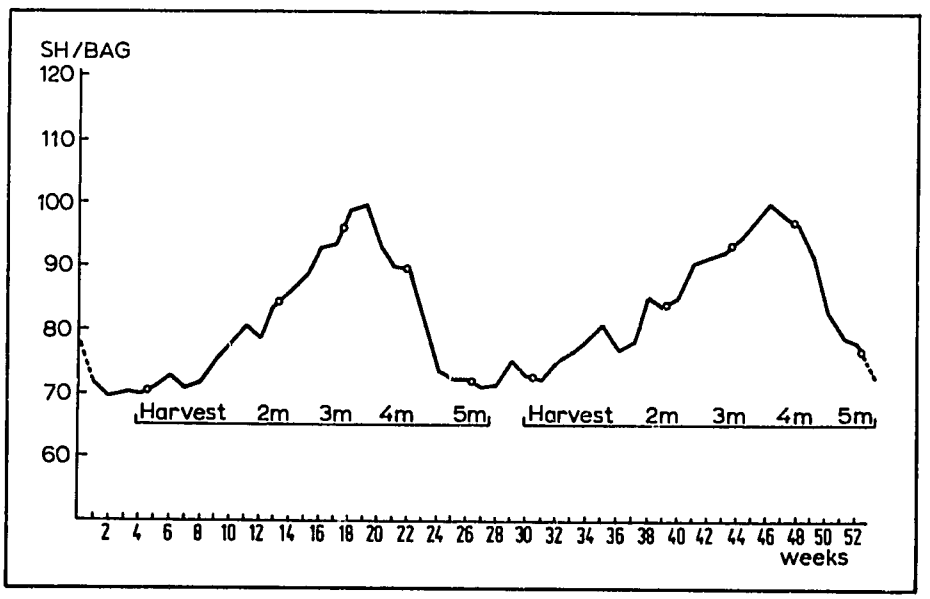


Figure 11. Average constant weekly wholesale prices for red potatoes in Wakulina market, Nairobi 1973-77 (two-week-moving-average) (Source: Ministry of Agriculture in Kenya, published by Durr and Lorenzl, 1980).

pense of the potato's productivity per ha and per unit time.

Furthermore, for a crop to expand, farmers must be willing to grow it. Developing country growers consider such factors as profitability and cash flow, suitability of the crop in the farming pattern, its usefulness for home consumption (especially small farmers), and risks involved. In many areas the potato crop meets these requirements, with the notable exception of the high risks associated with producing and marketing.

It may be concluded that the high productivity of the potato crop and the eagerness of farmers to grow potatoes are favorable aspects for the future expansion of this crop. However, despite these favorable factors, much depends on the possibility of reducing the price differences between ware potatoes and other foodstuffs.

Possibilities of reducing the cost of production per ha are rather limited. Breeding varieties resistant to PLRV, PVY, and Pseudomonas, improving tuber seed programmes, and in specific regions use of true seed may allow perhaps a 25% reduction in total production cost per ha. On the other hand, increasing prices and rates of application of chemical fertilizer and pesticides may be expected to partly offset these cost reductions.

Possibilities of reducing production cost per kg output are much greater. The following activities are recommended:

In specific regions within countries, attainable yields when all existing knowledge is correctly applied by growers should be determined through field trails. Such trials would help identify factors now limiting yield, as well as the potential yield increase from application of present knowledge. It is believed that in some cases yields could be doubled with only a slight increase in production cost per ha. This would allow a reduction of the ware potato price by as much as 50%, while increasing growers' profits.

Given the present high level of tuber seed costs, priority should be on better production and distribution of healthy and cheap seed. Existing and new techniques, such as the use of TPS, need to be tested and adapted to local conditions before widespread diffusion.

More attention should be paid to making it easier for farmers to produce potatoes under difficult growing conditions. Needed are varieties which are more tolerant to drought, heat, and frost. Such varieties would help growers increase yields with only moderate increases in production costs per ha.

More research should be conducted on the balance of haulm and tuber growth. Needed are more reliable tools for regulating this balance which could be applied by growers.

Better technologies are needed for storage of both ware and seed potatoes over the long, hot period. Attention should be paid to development and introduction of simple storage systems and means of transforming fresh potatoes into more easily stored products of high value to consumers. Breeding for keeping quality should also receive more attention that it has in the past.

If CIP continues its valuable work, with sufficient support from the industrial nations and the will of developing countries to improve their potato production, we believe that it may be possible to double the yield in the developing countries by the year 2,000. This will require a yield increase in the coming 2 decades which is almost twice as great as that of the last 15 years in percentage terms. In the year 2,000 the average yield level in developing countries would then be over 20 t/ha.

We believe that this yield increase is possible without a substantial increase in production costs per ha. If adequate storage technology is made available, this would allow potatoes to be available to consumers year around at about one-half their present price (discounting for inflation). This, in turn, would result in a strong increase in potato consumption. In many developing countries the potato could then become a staple vegetable, with average per capital annual consumption of around 20 kg. To meet this strong increase in consumption, it will also be necessary to double the area under potatoes in Africa and the Far East. These crude calculations illustrate how great an increase in production will be necessary to permit the potato to change its present role in the diet from that of a luxury vegetable to that of an important, staple vegetable.

Of course, potato development does not occur in a vacuum. Over the last 15 years wheat and rice yields increased in developing countries, and large quantities of cereals were imported and distributed at below-market prices. This points up the fact that increased production and use of potatoes will depend not only on technology improvement for this crop but also on improvement in other crops and the general economic policy framework of world development. Taking all factors into account, we believe that relative potato prices will fall over the coming 2 decades in most developing countries. This, in combination with the eagerness of many farmers to grow potatoes and the high productivity and nutritive value of the crop, lead us to conclude that in many areas where the potato is now a luxury vegetable it will become a staple vegetable, and in some places where it is now a staple vegetable it may become a basic staple food. However, in many parts of tropics and sub-tropics the potential yield of the potato crop is considerably lower than that in the temperate zone. We feel that it is unlikely that in the near future in those parts of the world potatoes can become competitive in price with alternative food crops which are better adapted to local growing conditions.

As a final note, we wish to point out that limited potato production in low-potential areas does not necessarily lead to low consumption in these areas. Many can be supplied by adjacent or nearby high potential areas. As transportation systems improve the high potential areas can be expected to supply growing urban market more cheaply. Conditions vary drastically from country to country. Hence, each national programme should study the potential of the potato as a food crop under its own conditions and in relation to other food crops. Such studies should analyze the present situation and prospects for both potato production and consumption.

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Research Papers

GROWING POTATOES FROM TPS. CURRENT AGRONOMIC KNOWLEDGE AND FUTURE PROSPECTS.

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Commercial potato production traditionally has been based on using tubers for propagation. This practice, especially in developing countries, is a major limiting factor in potato production because of high cost and unavailability of good quality seed tubers for planting. Perishable seed tubers, as well as high cost plus logistics related to storage and transportation, are constraints of major importance in tropical potato production characterized by high temperature and rainfall.

Research at the International Potato Center (CIP) has focused on the feasibility of using true potato seed (TPS) as an alternative to the traditional seed tuber utilized for the production of potatoes.

Use of true seed to produce potatoes offers several advantages, including: (1) Its cost is low. It can reduce total potato crop production cost by 50% to 70%. Thus, subsistence farmers who previously lacked a source of low-cost, high quality tuber seed, can use true seed to grow potatoes in their backyard gardens. (2) It can be stored and distributed easily and more economically. (3) It carries fewer pathogens, especially viruses, from season to season. (4) It would make possible expansion of potato cultivation into farming areas previously unable to produce potatoes, due to lack of good quality seed tubers or into warm humid tropical areas where seed tubers could not be produced or stored.

Agronomic research to develop technologies to produce potatoes form TPS has followed two approaches: (1) Transplanting TPS seedlings from the nursery to the field, (2) Direct sowing TPS to the field. Potatoes produced by either approach can be used for consumption or as seed tuber, or both, depending on the specific needs and conditions of the farmers.

TPS seedling production, transplanting and management

Agronomic research at CIP has concentrated from the beginning on development of nursery and transplanting technology that uses low-cost, locally available materials and as little labor as possible. TPS can be sown in trays or directly into seed beds made in the ground in a shaded nursery where 75-80% of the sunlight is transmitted. Seedling emergence is faster and more uniform and growth is more vigorous in shaded nurseries than when seedlings are exposed directly to sunlight in warm climates. The effect of shading is most pronounced when soil and air temperatures are higher than 25°C. The superior behavior of seedlings in a shaded nursery can be attributed to the effect of reducing soil and air temperatures.

Excellent results were obtained when the seed bed mixture was 1 part shredded peat moss and 1 part sand plus inorganic fertilizers. Several other formulations have been investigated with good results, including a compost of bean plant residue and leaf litter from tropical forests.

Emergence normally occurs between 8 and 10 days after sowing. This is influenced mainly by the progeny itself and the soil temperature. A week or 10 days after emergence seedlings are thinned to approximately one every 3 centimeters. A seedling area of 3 x 5 centimeters is sufficient to provide a good root block for the seedlings at the time of transplanting.

Best results have been obtained when seedlings grown under shade were hardened by exposure to direct sunlight for 7 to 10 days before transplating.

Transplanting is done when seedlings are about 10 centimeters high (4th to 5th leaf stage). This stage is reached in about 4 weeks after sowing in warm climates and up to 6 weeks in cooler environments.

Best yield results in warmer climates are obtained from seedlings transplanted with a seed bed substrate block covering the roots. Seedlings transplanted before tuber initiation at transplanting yielded significantly higher than those bearing small tubers.

Fertilizer is incorporated during land preparation with half of the nitrogen being applied at the time and the second half during the last hilling. As in the nursery, phosphorus is critical in the early stages of establishing potato seedlings in the field. Nitrogen also has a very important role in enhancing vegetative growth for higher production potential.

Under tropical conditions, it is of great importance to assure adequate plant density for obtaining a fast and sufficient ground cover and a high production of tubers. This is critical under conditions of high temperature, moisture stress and attack by insects such as cutworm. The minimum number of seedlings that should be considered to obtain the best yield is 3 to 4 seedlings either per hill or in 30 centimeters of row space. No reduction in tuber size was observed with up to 5 seedlings per hill when compared with lower densities.

Current information indicates that hand weeding during the hilling process is the most satisfactory method of weed control. Potato seedlings are extremely sensitive to herbicides during the period following transplanting.

At the nursery stage, when seedlings are grown in seed beds containing compost of plant residues, soilborne pathogens may be present. Rhizoctonia, Fusarium and Pythium are the most serious pathogens causing damage to seedlings. Application of chemicals that are absorbed by the roots, such as benomyl (Benlate), at the recommended rate has given good protection. Pests affecting seedlings in the nursery are of certain importance in tropical climates. Distributing a contact insecticide in a powder form on the soil around the nursery seed bed provides an effective barrier for cutworms and ants.

TPS hybrids and open-pollinated progenies

Hybrids are superior to open-pollinated progenies in yielding ability. Four hybrids and one open-pollinated progeny are the best, so far identified: Atzimba x DTO-28, LT-1 x DTO-33, LT-2 x DTO-33, Atzimba x R-128.6, and DTO-33 op. (Origin of parental material: Atzimba-Mexico; DTO-28 and DTO-33 - University of Wisconsin; LT-1, LT-2 and R-128.6 - International Potato Center). All meet satisfactory uniformity standards in terms of growth, earliness, maturity and tuber characteristics, and adequate to high yielding ability. However, these progenies do not have resistance to major diseases and pests that effect the potato. Seed of these 5 progenies is being produced under disease-free conditions and small amounts will be available for distribution. Scientists from national programs needing any of these progenies for further work, should request the parental clones from CIP.

CIP scientists are evaluating TPS progenies under different environments in Peru and it is expected that superior material in terms of yield, resistance, earliness and uniformity will be available for distribution in the near future.

Transplanting TPS seedlings from the nursery to the field has several advantages over direct sowing of TPS: (1) Development in nurseries permits careful management to produce vigorous seedlings for transplating; (2) Growing time in the field is approximately 30 to 40 days less when seedlings are raised in a nursery; and (3) Seedling transplanting is already used by small farmers in the tropics for rice production and for many vegetable crops, thus facilitating adoption of TPS transplanting technology into their existing farming practices.

Research needs

Research on potato production from true seed at CIP and elsewhere has been underway for a short time. To improve our present technical knowledge, research in several areas should be emphasized: (1) Breeding, selection and evaluation of true seed progenies for high yield, resistance to important diseases and pest, earliness, and tuber uniformity, and develop methods for hybrid seed production; (2) Study those factors related to flowering, pollination, fertilization, fruit set, and seed set, aiming at the production of high quality seed. This knowledge will permit definition of suitable methods for seed production; (3) Physiological and agronomic work to improve seedling vigor at the nursery and field level; (4) Agronomic practices to improve and reduce the cost of production components, particularly identifying proper soil mixes for nurseries, preventing stolon formation in the nursery, identifying selective herbicides and identifying methods for diseases and pest control; and (5) On-farm research to evaluate the technologies, their socio-economic value and farmer acceptance.

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THE POTATO, AS A SMALL FARMER'S CROP

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Summary

Recent advancement of potato production in the developing parts of the world forms the basis of the potato for being treated as a small farmer's crop there. The small farmer's problems are, among others, inadequate inputs like seed, fertilizer and irrigation, inability to receive institutional credits, not enough access to storage facilities, besides lack of or inadequate literacy. Governmental and institutional supports when arranged for them would make the small-farmer potato production much more viable, leading to ultimate acceptance of the potato as a major crop in the tropics.

Introduction

Even though the potato originated in that part of the world which is yet to be termed as developed, it is known, by and large, as a crop of the developed world where farmer's holdings are large. The potato has, therefore, been treated as rather a big farmer's crop.

Recent trends of potato production

However, during the last 30 years the temperate or the developed regions of the world had only small increase in total production of potato, there being even a decrease in area grown to this crop. Contrary to this, in the developing regions, the total potato production rose to 249 percent, with rise in both acreage and per hectare yield by 55 and 60 percent respectively. This is a clear indication that this crop has received in the recent past a wide acceptance in the developing world.

Tropical potato vis-a-vis small farmer

This signifies that the potato is now an important crop in the tropics where the greater part of the developing regions belong. But these are the areas where the growth of population is generally very high, the density of population is often very thick, and the size of the holding is small.

In Bangladesh, nearly any farmer is a small farmer. According to a Master Survey of Agriculture in 1967-68 in Bangladesh, 52.65% farms of the country had the size of less than 2.5 acres (1 hectare). The proportion of small farms has since increased because of the existing law of inheritance.

At least two-thirds of the potato farmers have less than one hectare, and hundreds of thousands of them do not grow potatoes even on one acre of land.

There are hundreds of thousands of families who raise potatoes in their backyards or kitchen gardens, and they are even smaller than the small farmers. The production of potato in the tropics has been thriving rather through small farmers than the big ones. The Indonesians, the Philippinos, the Sri Lankans, many Indians and almost all of the African potato growers are small farmers. In Latin American Countries, also most potato farmers are presumably small ones.

Small farmer's problems

Elias, et al., (1981) found the small farmers have the least per ha yield of potato, and the lowest benefit-cost ratio. Among the small farmer's constraints were payment of high interest rates due to the inability to obtain institutional credits, inadequate inputs like fertilizer, irrigation and seed.

Seed cost, the lion share of the total cost

Cost of quality potato seed used in the Meerut Govt. Farm, India constituted as much as 51.2 percent of the total cost of production (Sushil, et al., 1977), and in Bangladesh cost of quality seed was 42.6 percent (Ahmad and Kamal, 1980).

Total cost of production of a hectare of potato in the government farm of CPRI, Simla, was $ 768 with net profit of $ 838, an output input ratio of 2.1 for crop of 17.25 tons (Sushil, et al., 1977). In contrast a farmer of Simla produced 9.94 tons with the output-input ratio of 1.5. Low quality seed in the case of the latter was found to be the main reason of low yield and profit. Ahmad and Kamal (1980), drawing a comparison among rice, wheat and potato, placed the production-costs of these crops at US$ 365, 255 and 822 respectively per ha. The profits as estimated by them were much higher in the case of the potato, this being as much as US$ 485, against rice and wheat's $ 265 and 170 respectively. One can attain such profits only when one can spend so much.

Reasons for small farmer's interest in potato

Potato being a labour-intensive crop, enables farmers to engage themselves and members of their families in its production. Often this self-employment is not included in the cost of production figures and their estimates based on other inputs only, make the crop rather profitable. Opportunities to raise early crops which pay high price per unit quantity of tuber, ability to harvest the crop even long before its maturity, availability of so-called indigenous varieties of potato whose seed rates range between 1/3 and 1/2 of that used for exotic varieties, and 'Indigenous seed's good keeping quality' have always been tempting enough for Bangladesh farmers to produce potatoes.

Usefulness as an inter-cropping commodity

In Patna, India, the net mean return from trials over 3 years, increased from Rupees 6210 to 6611 per hectare by inter-cropping of wheat in potato, the latter having been planted 30-40 days after potato (Singh et al., 1978). By conducting experiments at seven locations in Bangladesh, Rahman and Razzaque (1978) obtained net incomes ranging from Taka 4,998-10,089 per acre from sugarcane alone and Taka 5,758-13,937 from the combination of sugarcane and potato, planting sugarcane and potato on the same date around middle of November. The cane yield did not reduce; it rather increased because of potato, the cane crop having, presumably, been benefited from spill-over effect of clean management attending the potato crop.

Suggested supports to small farmers

It is probable that potatoes in the tropics of the year 2000 A.D. will be a small farmer business. We shall do yeomen service to the cause of the potato if constraints experienced by small farmers are taken care of adequately. These can be in the following ways:

a. Making available all the credits that are needed by the farmer, through institutional means, so that he does not have to pay as interest more than what the big farmer pays.

b. Since potatoes of the tropics are grown more during the winter season which is often dry, irrigation facilities should be available institutionally, as far as possible. In Kashimpur of Bangladesh, performance has been excellent, because of credit, seed, irrigation, fertilizers, pesticides, and supervision.

c. The proportion of seed cost being so high, techniques that reduce the cost of seed would be of immense benefit to the small farmer. The recent technology to use true seed production of tubers when adapted in commercial scales will fulfill the need of the small farmer more than anything else.

d. In view of small farmers being compelled to sell their produce right after harvest, sometimes even from the field, because of non-availability of storage facilities of even temporary nature, arrangements for co-operative ware houses in the potato-growing areas will be of immense value.

e. The growth of cold storages and the growth of potato production in India and Bangladesh have increased in a parallel manner in recent past. The growth of cold storage industries should be adequate during the Eighties and Nineties.

Conclusion

Despite all kinds of constraints experienced for the growing of potato in the tropics, it is mainly small farmers who have brought potato production there where it stands now. It is they who will push it farther through the Eighties and Nineties. The more this fact is realized and accepted and the more the small farmers are supported by governments and institutions, the better is the future of the potato in the developing world.

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TRANSFER OF POTATO TECHNOLOGY IN THE TROPICS

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Summary

The potato, the most important vegetable of the world, with great potentials for serving as a food in partial substitution of rice and wheat in the tropics, has yet to make a major break-through there for several reasons among which technology transfer is prominent. The potato has so many technologies for production, storage, utilization and marketing already available, and await transfer to appropriate people like farmers and consumers. There exists many transfer-media which can be used as a bridge between 'research' and farmers and consumers, but these are yet to be exploited to the fullest extent, and in some cases even to the barest extent. Attention in extension has been mainly for promotion of food grains production, and potato happens to remain neglected. There is the question of changing the attitude and out-look in favour of potato. If various organizations concerned directly or indirectly with production, preservation and utilization, divert a part of their attention towards potato, transferring potato technology will be greatly improved.

Introduction

It is well-known fact that potato, the most important vegetable of the world, which has the great potential for serving as a staple food or also in partial substitution of rice or wheat in the tropics has recently gained greater importance. This has been so despite not much activity for the transfer of potato technology to those for whom technologies are meant, such as farmers and consumers. Unlike many other commodities, potato culture has many aspects including production, storage, utilization and marketing which are intricate and at times complicated. Technologies in each of these areas are already available in the west.

In some areas of the tropics also these have been developed to a fair extent and these are waiting for transfer to the appropriate people.

Basic inadequacies

A tropical farmer is usually a small farmer. He is often either illiterate or with a low literacy level. His knowledge about modern agriculture may be quite limited. Mechanization is either completely absent or is in a rudimentary form.

For extending a crop, a technology or a knowledge of a crop area of possibly 200 acres, an extension worker may need to come in contact with as many as 200 farmers. Farmers of the tropics may be even inaccessible because of absence, inadequacy, or inferiority of communication because of non-availability of transportation facilities. An extension worker may find it difficult or impossible to reach them through literature such as books, booklets, pamphlets and leaflets.

Status of potato

The potato might be an absolutely new crop in a region or country, and for that reason may confront all the odds that are faced by an exotic new crop when introduced to a new area. The potato may be only a vegetable like so many others and not a staple food crop like rice and wheat, thus not receiving the attention that is drawn by a staple food crop, a commodity of an immediate and absolute need.

Storage

It is difficult to find facilities for storage of the tubers which happen to be harvested at a time when summer sets in, and as the time passes the ambient temperature goes on rising. The tropical tubers can be given a cool environment only by the installation of refrigeration which undoubtedly is very expensive.

Post-harvest technology

Potatoes in various processed forms ready for instant reconstitution or cooking into various types of food are a luxury for a tropical consumer.

In order to understand the question of transfer of potato technology in the tropics, all these matters must be taken into account. It is heartening to find that, inspite of all these difficulties, the potato has made quite a bit of advancement. The main credit for this must go to the potato itself, which produces maximum amount of quality food in the form of calories, minerals, and vitamins per unit land area, time and water resource.

Responsibilities of various organizations

For the transfer of potato technology adequately in a country, it will be needed to make concerted efforts involving various organizations that are directly or indirectly concerned with potato production and preservation. The responsibilities of such organizations are outlined below:

Research organization

a. Find appropriate technology through research.
b. Train extension officers of leading potato areas.
c. Prepare and publish potato literature.
d. Develop linkage with other potato-oriented agencies.
e. Hold workshops and seminars on various aspects of potato.

Extension organization

a. Groom extension officers to be able to deal with potato matters.
b. Multiply and distribute potato literature.
c. Encourage consumption of potato through extension workers.

Organization responsible for seed production supply and service

a. In addition to seed production in large scale, develop a realization among seed farmers and their neighbours about the ultimate objective of seed production of table potatoes.
b. Arrange demonstration of the quality of produced seed of different varieties, as promotional activity.

Banks

a. Make credit availability easy.
b. Make concerned bank managers aware of the importance of potato.

Private associations, like cold storage associations

a. Develop a realization among their members that potato starts long before they are brought to the doorsteps of a cold storage, and they have a role to play there too. No production means no storage.
b. Avoid some of the difficulties that discourage the farmers.
c. Associate with research and extension in the programmes of transfer of technology.

The agriculture information service

a. Develop a special potato cell capable of furnishing all information with regard to the promotion of potato.
b. Multiply appropriate literature on production and utilization aspects of potato and distribute them to concerned persons throughout the country.

BACTERIAL WILT OF POTATO IN BURUNDI

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Summary

Most potatoes (10,000 hectares) are grown in Burundi at an altitude between 1800 and 2300 m. The climate of this area is characterized by average temperatures of 14° - 18°C, a total annual rainfall of 1600 mm and a dry season of 3 - 4 months.

A programme for the improvement of potato cultivation was started two years ago in Burundi. The first goal of this programme was to provide farmers with clean seed of potato cultivars with high yields and resistance to late blight. Research is also taking place on an integrated programme for the control of bacterial wilt caused by Pseudomonas solanacearum, biotype 2 or race 3, which is also an important disease of potatoes in Burundi.

The research of cultivars resistant to P. solanacearum local strains, in local potato cultural conditions will be a first approach to bacterial wilt control. Evaluation criteria will include not only the time to wilting and the rate of wilt, but also the incidence of latent infection of tubers after harvest.

Latent infection of tubers plays a major role in the spread and development of the disease. Infected plants remain symptomless particularly at low ambient temperature during the dry season culture in humid valleys.

A propagation and diffusion programme from a nucleus of imported or locally reconstituted seeds free of bacteria is thus being progressively realized. Success of this programme will depend on maintaining good crop rotation, the roguing of plants showing wilt symptoms as well as those adjoining the infected plants, in the field and at harvest time.

For control of the soil borne infection, a rotation with a fallow of 1 1/2 to 2 years appears to be sufficiently effective in reducing the wilt potential of a contaminated land. The experiment has also demonstrated cleansing effect of the long dry season which subjects the soil to an intense desiccation and thereby reduces

soil inoculum. In an attempt to enhance the effect of rotation on soil borne inoculum, new experiments have been undertaken to compare a weed fallow with other crops (maize, wheat, beans or peas) which can be rotated with potatoes. Initial results suggest that soil disturbance during cultivation which accelerates the destruction of the pathogen's habitat has a greater effect than the nature of the rotation.

Other trials will also attempt to evaluate the effect of maize, beans, or peas sown between potatoes planted at larger spacing (80 x 90 cm) to limit the spread of the disease in the field and thus the increase of soil inoculum, and to improve the selection of plants destined for farmer's seed store.

Introduction

Most potatoes (10,000 hectares) are grown in Burundi at an altitude between 1800 and 2300 m at average temperatures of 14 - 18°C, a total annual rainfall of 1600 mm, and a dry season of 3 - 4 months.

There are three potato crops per year: two in the hills during the wet seasons (October - January and March - June) and one in the humid valleys during the dry season (June - September). At present, growers cultivate potatoes principally during the dry season to escape damage caused by potato late blight (Phytophthora infestans). Potatoes are often grown in association with beans or maize. Farmers produce their own seed without any selection, or buy them at the market, or even leave small tubers in the soil at harvest time. Average potato yields are low, between 3 and 6 tons per hectare.

A potato improvement programme was started two years ago in Burundi to provide farmers with clean seed of potato cultivars with high yields and resistance to late blight. Research is also taking place on an integrated programme for control of bacterial wilt caused by Pseudomonas solanacearum, biotype 2 or race 3 (Buddenhagen and Kelman, 1964). Bacterial wilt is an important disease of potatoes in Burundi, with yield losses between 30 and 90%.

Epidemiology

The two main sources of primary inoculum causing bacterial wilt are infected tubers and infested soil.

Seed borne wilt plays a major role in the spread and development of the disease, as shown at the Munanira station. A highly infected crop of Sangema variety was sorted during 3 months storage (28°C and 60-90% R.H.) and 75% rotting tubers eliminated. The apparently outwardly healthy tubers were planted in non-infected soil which produced 47% of wilting plants. Disease spread from one plant to the next via the root system (Kelman and Sequeira, 1965) was avoided by a plant spacing of one meter, and with separate hilling for each plant. Under these conditions, selection of healthy plants in the field and at harvest time allowed the reconstitution of a nucleus of almost bacteria free tubers. Incidence of wilting plants was reduced from 47% to 1,9% and to 0,5% in the next propagation under the same conditions (Autrique 1980). In this experiment, 30,7% of tubers coming from wilting plants have nevertheless given healthy plants in subsequent planting. They probably came from plants wilting late in their growth cycle. It has also been noted that the bigger the tuber, the higher was the rate of bacterial wilt.

Low ambient temperatures can also favour latent infection of plants (Ciampi and Sequeira, 1980). Sangema potato tubers from a different source with different qualities planted in a humid valley at Kisozi (2100 m) during the dry season (average temperatures below 15°C with minimum of less than 10°C) resulted in less than 1% wilt infected plants. However the tubers coming from this field, planted in different stations 5 months later on hills during the wet season resulted in 10 to 30% wilted plants. It appears therefore that production of seed during the dry season in the humid valleys is not advisable.

In order to assess importance of soil borne infection and its possible control through crop rotation, a field experiment with Arka potato variety was carried out at Kisozi (2100 m) on contaminated land (21% wilt). Replanting potatoes in this field after only one month of fallow, promoted an explosive development of bacterial wilt (96%) during the first month following crop emergence, with a nearly total loss. A third culture of potatoes on the same plots, after four months of fallow, (June to October) demonstrated the cleansing effect of the long dry season which subjects the soil to an intense desiccation. Wilt was reduced to 51%. In this experiment, a rotation with a fallow of 1 1/2 to 2 years appears to be sufficiently effective in reducing the wilt potential of contaminated land.

Prospects for control of bacterial wilt

The selection of cultivars resistant to local strains of P. solanacearum will be a first approach to bacterial wilt control. Evaluation criteria will include not only the time to wilting and the rate of wilt, but also the incidence of latent infection of tubers after harvest.

A propagation and diffusion programme from a nucleus of imported or locally reconstitued (Autrique, 1980) seed tubers free of bacteria, is also being progressively realized. Success of this programme depends on maintaining good cultural practices at the potato stations: a minimum two years crop rotation; roguing of plants showing wilt symptoms as well as those apparently healthy plants adjoining infected plants; and further roguing at harvest.

New experiments have been undertaken to compare a weed fallow with other crops (maize, wheat, beans, peas) which can be rotated with potatoes. Initial results suggest that soil disturbance during cultivation which accelerates destruction of the pathogen's habitat has a greater effect than the nature of the rotation. It would therefore seem advisable to recultivate infected land after a potato crop rather than leave it fallow.

However, potato growers don't often practice crop rotation and also refuse to rogue out wilting plants. Experiments will therefore attempt to evaluate the effect of maize, beans or peas sown between potatoes planted at larger spacing (80 x 90 cm) to limit the spread in the field and thus limit the increase of soil inoculum, and to improve the selection of plants destined for the farmer's seed store.

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POTATO INSECT PESTS IN BRAZIL PRESENT STATUS AND FUTURE TRENDS

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Introduction

Potato is a very important crop for Brazil, nevertheless the consumption is still very low (11 kg/capita/year) and average national yield is only 10 t/ha. Usually two crops are made per year totaling 200,000 ha. Production technology varies with yields from 3 to 45 t/ha. Recently improved technology in some areas has increased total production even though total acreage has reduced.

Numerous and important insect pests frequently are causing lowered yields and increasing production costs. Directly through feeding on leaves, stems, and tubers or indirectly through virus transmission, insect pests of potatoes are very important and a limiting factor in developing efficient potato production technology for Brazil.

Up to now control of insect pests of potatoes in Brazil has been a fixed pattern scheme without paying attention to insect presence and numbers. This situation became catastrophic in seed potato production where almost 50 kg of insecticide (active ingredient)/ha are used during one single season. Because of this high insecticide selective pressure, pest resistance, destruction of beneficial insects and pest ressurgence, higher residue levels, higher production costs, and environmental pollution have arisen, demanding development of rational integrated pest management strategies.

This paper describes briefly the potato pest situation in Brazil, the past and future for overcoming the above mentioned problems, and those described by Barbosa and Franco (1981), Gallo (1970) and in Empresa Brasileira.

Important potato pests in Brazil

The green peach aphid (Myzus persicae, Sulzer, Homoptera: Aphididae) is the most important potato pest in Brazil for seed potato production. Its importance is due to its efficiency in transmitting both

PLRV and PVY. Mainly because of the complex GPA - Potato Viruses, Brazil is still dependent on seed potato imports from several foreign markets. Growing potatoes and other solanaceous plants year around, very high populations of viruliferous aphids develop in constant migration from infested to clean fields. Other potato infesting aphids do occur in Brazil but their importance is much lower. Predators and parasites of the green peach aphid in Brazil exist but are not well known.

The potato "pinworm" (Diabrotica speciosa, Coleoptera: Chrysomelidae) and the flea beetle (Epitrix spp., Coleoptera: Chrysomelidae) complex constitute very important potato insect pests in Brazil both for seed and table potato production. During their larval stage they feed on developing tubers making superficial holes which lower the product quotation in the market. The adults feed on the leaves at very high numbers causing the tops to die earlier, reducing yields up to 40%. Predators and parasites of this pest complex in Brazil are not well known.

The vegetable leafminer (Liriomyza huidobrensis Diptera: Agromyizidae) is becoming a very important pest of potatoes in Brazil and in some growing areas it was responsible for up to 30% yield reduction in the last two years. During the dry season crop they develop in large numbers and the larvae cause the total destruction of foliage. This insect has a very wide geographical distribution in South America and a very wide host range (Boock et al., 1981). It was in Brazil several years ago but only recently it became a key pest of potatoes. There are several predators and parasites of leafminers in Brazil but their taxonomy and efficiency are not well known.

Several other insect pests damage potato in Brazil but their importance is secondary. In this category we would have the tuber moth (Phthorimaea operculella, Lepidoptera: Gelechiidae), several species of wireworms (Coleoptera: Elateridae), the black cutworm (Agrotis ipsilon, Lepidoptera: Noctuidae), the potato aphid (Macrosiphum euphorbiae), Homoptera: Aphididae), the southern green stink bug (Nezara viridula, Hemiptera: Pentatomidae), the blister beetles (Epicauta spp. Coleoptera: Meloidae), several species of white grubs (Coleoptera: Scaraboeidae) and several insects and mites of minor importance. Because of heavy use of insecticides the tuber moth is not an important field pest. Since we do not store table potatoes in Brazil it only becomes problem for seed potatoes under storage.

The control of potato insect pests in Brazil

In South Central and Southern Brazil potato production technology is more developed and where most of the insecticides are used. Basically every grower uses 2-5 kg. a.i. of a granular systemic insecticide at planting time, and from emergence to harvest 2 or 3 insecticides and 1 or 2 fungicides are applied twice a week. Granular systemic insecticides commonly used are phorate, disulfoton, aldicarb and carbofuran. Systemic foliage sprays utilize mevinphos, phosphamidon, vamidothion, metamidosphos, oxydemeton, acephate, dimetoate, carbofuran, and some others. Foliage contact and ingestion insecticides used to control chewing insects are malathion, methyl parathion, ethyl parathion, carbaryl, diazinon, endosulfan and, lately, the synthetic pyrethroids.

With present prices of chemicals, labor, and fuel and with the side effects of unrestricted use of insecticides, the situation became catastrophic requiring intelligent and rational strategy. Insect pest control experiments were installed in the seed production area of the State of Santa Catarina and some growers are already utilizing results (Barbosa and Ogawa, 1981). Application of 2 kg/ha of aldicarb at planting time, plus an application of 500 g/ha of pirimicarb whenever a population of 10 apterae/100 leaves develops, plus 5 g/ha of deltametrine spread at every 15 days gave a better control of aphids and chewing insects than the usually used standard treatments. Fortunately there is a general move in Brazil towards the safer and more efficient use of pesticides in general which will make any new findings on integrated pest management quickly accepted by the extension service and growers.

Research items to be emphazised in the future.

Until recently research on potato insect pests was marginal with great necessity for improvement. Presently potato research in Brazil is well organized into a National Program and entomological research will be a priority.

A great potential exists for long term research for development of new cultivars resistant to both insects and pathogens. Breeding programs must work closely with entomologists and plant pathologists for maximum efficiency.

Studies of insect pest population dynamics and populations threshold levels are needed as this is basic to any future integrated pest management program.

Diversity of predators and parasites of potato pests in Brazil is almost unknown and their identity, number, importance and behaviour is not understood.

For chemical control it is necessary to evaluate minimum dosages, insecticide impact on beneficial insects, residue levels on table potatoes, and insect resistance to insecticides. Insecticides are extremely important in production and we have to learn benefits from them and avoid their side effects. It will be very difficult to produce great quantities of potatoes without any insecticide but we have to find alternatives to the present abusing situation.

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USE OF NATURAL DIFFUSED LIGHT FOR THE STORAGE OF SEED TUBERS

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Introduction

The effect of both natural and artificial light on reducing sprout elongation has long been known (Burton, 1966). Its use as a preplanting green sprouting technique has been widely practiced, particularly in Europe (Rastovski and van Es 1981). Although use of natural diffused light during storage of seed tubers has been practiced, it was not until recently well described (Booth and Shaw, 1981) and the technique is not widely known or used in developing countries.

This paper reports results of three years trials to evaluate the potential of the technique in a traditional potato growing area of a developing "tropical" country.

To fully evaluate a seed storage technique, its effect on both the storage behavior and subsequent field performance of stored tubers needs to be examined. Similarly, the technology must be evaluated under farmer as well as experiment station conditions.

Materials and methods

Experiment station trials: Storage and field trials were conducted at the International Potato Center (CIP) Experiment Station, La Victoria, Huancayo, Peru (3200 m above sea level).

Storage trials: In 1978, 4 replicates of 66 well selected 100 g seed tubers of eight varieties were used. In 1979 and 1980, single lots of 100 seed tubers of 17 and 24 varieties, respectively, were used per treatment. All tubers were stored in seed trays for 180 days. Dark stored tubers were placed in a naturally ventilated adobe potato store and the light stored tubers were kept in a natural diffused light store (International Potato Center, 1977). The average store temperature during the storage periods varied between 11° and 13°C. At the end of the storage period, the mean length of the longest sprout per tuber and the mean number of sprouts per tuber were measured on 10, 33 and 25 tuber samples in 1978, 1979, and 1980, respectively. Total storage losses were calculated from initial and final weight of all tubers. Final weight of dark stored tubers was measured after the necessary desprouting which was done immediately prior to planting.

Field trials: Only in 1978 were detailed field records made. Percentage emer-

gence was determined from the average emergence of four replicate plots planted with all the tubers remaining from the storage phase of the trial. Final yield was calculated from the average yield and area of these plots.

On-farm trials were conducted with farmer cooperators in the Mantaro Valley, where the CIP, Huancayo Experiment Station is located. In 1978 trials were conducted on 4 farms. This was extended to 6 farms in 1979 and 1980.

Storage trials: In all cases farmers' seed tubers of varieties that they made available were used. For each farm and variety two 100 kg lots of seed tubers were used. One lot was stored according to the farmers' normal practice and the second was stored in natural diffused light. The farmers' storage practices varied but always consisted of piling tubers up to 1.0 m deep in dark, poorly ventilated rooms, in the house roof space, or on a covered patio in which case some tubers were exposed to diffused light. In 1978 the light stored tubers were kept in 10 seed trays placed outside on a covered patio. In 1979 and 1980 the seed trays were replaced by shelves constructed of locally available rough timber. At the end of the farmers' normal storage period, which ranged from 2.5 to 6 months, sprout lenght and number were measured on 100 tuber samples and total storage losses determined from the weight of all tubers.

Field trials: The tubers remaining from the storage treatments were planted by the farmer in two plots within his other plantings. The farmer's stored seed was desprouted immediately prior to planting according to their normal practices. Light stored seed was not desprouted. Within both plots an area planted with 100 tubers was marked and used for emergence calculations. Throughout the growing period, the crop was looked after by the farmer according to his normal practices. In 1979/1980 and 1980/81 final yields were calculated from the yield and area of the whole plots.

Results and discussion

Both experiment station and on-farm results of the storage trials (Table 1) clearly demonstrate effectiveness of natural diffused light in reducing sprout elongation, increasing sprout number, and reducing total storage losses. In general there was greater variability in the results of the on-farm trials, reflecting the variability in storage duration, method and conditions.

In all cases, inhibition of sprout elongation during light storage was sufficient to eliminate the need for desprouting due to excessive sprout growth. In all trials and with all varieties light increased the number of sprouts produced. However, the degree to which this happened varied greatly between varieties; some varieties produced an adequate number of sprouts while others remained essentially apically dominant at the end of the storage period. Storage losses due to decay were very low in all cases, including the on-farm trials.

In the dark and farmer stored tubers, losses were due to a combination of moisture loss and sprouting. In the light stored tubers losses were almost entirely due to moisture loss. Although the weight loss atributable to excessive sprouting is controlled by diffused light, additional moisture loss from the tubers probably occurs due to their greater exposure in this storage method. Weight losses of the magnitude recorded in light stored tubers are considered acceptable for farmers planting their own stored tubers into well prepared field. Where seed tubers are to be sold any loss of weight will normally result in loss of revenue.

Table 1. Effect of natural diffused light on the storage behavior of seed tubers.

	1978 Dark stored Light stored	1979 Dark stored Light stored	1980 Dark stored Light stored
Experimentation station trials 1/			
Sprout length 3/	18.8 1.4	25.0 2.3	21.4 1.8
Sprouts/tuber 4/	1.6 4.0	1.2 2.4	1.5 3.8
Storage losses 5/	15.3 8.3	- -	25.2 11.5
On-farm trials 2/			
Sprout length 3/	9.8 0.8	16.2 1.1	13.2 1.2
Sprouts/tuber 4/	1.6 3.2	1.3 3.1	1.8 3.8
Storage losses 5/	32.0 13.5	18.1 10.7	16.4 7.5

1/ Mean results of 8, 17 and 24 varieties in 1978, 1979 and 1980, respectively.
2/ Mean results of 4 farmers and 4 varieties in 1978, 6 farmers and 9 varieties in 1979 and 5 farmers and 9 varieties in 1980.
3/ Mean sprout length in cm.
4/ Mean number of sprouts per tuber.
5/ Mean total storage loss (%).

The rate of field emergence varied considerably between seasons, farms, and varieties, but in all cases light stored tubers emerged earlier and more uniformly (Table 2). Use of natural diffused light storage resulted in increased yields in both experiment station and on-farm trials. Actual yields and percentage increase in farm yields due to the use of light varied considerably, but on all farms and with all varieties the response was positive.

During the three year period of the on-farm trials, it was observed that the farmers' appreciation of the potential benefits of the use of natural diffused light grew. Those farmers who traditionally stored in piles on a patio had previously observed the effects but were uncertain of how to apply them. All farmer cooperators appreciated the value of sound seed tubers with short sturdy sprouts and were enthusiastic about being able to avoid the costs of time and labour of desprouting. Because of this, they showed interest in the technique even before they saw the earlier emergence and increased yields. During the period of the trails some of the farmers modified and improved their traditional storage practices accordingly. Additional advantages reported by farmers were that the light stored tubers were in acceptable planting conditions for a longer period of time than traditionally stored seed

Table 2. Effect of natural diffused light storage on the field performance of seed tubers.

	1978-79		1980-81
	Experiment Station trial 1/ Light stored Dark stored	On-farm trial 2/ Light stored Dark stored	On-farm trial 3/ Light stored Dark stored
Field emergence 4/	49.5 91.6	51.2 79.7	22.1 44.3
Final yield (t/ha)	24.6 28.8	13.6 16.4	16.8 19.9
Yield increase 5/	17.1	20.6	18.5

1/ Mean of 8 varieties
2/ Mean of 6 farmers and 7 varieties
3/ Mean of 5 farmers and 7 varieties
4/ Field emergence (%) 25 days after plants
5/ Yield increase of light stored tubers over dark stored tubers (%).

which would allow greater flexibility over planting and hence harvesting dates and that the cropping period could be reduced.

Simultaneously, with these trials adaptation of this basic technology to seed tuber storage needs in other countries was being examined jointly with national research and extension scientists. This has resulted in a range of store designs and structures based on this basic technology, but using local materials. These are being investigated and transferred to farmers field in numerous potato growing countries (International Potato Center, 1980).

Conclusion

Results clearly indicate the technical potential for using natural diffused light seed stores as simple low-cost alternatives to more sophisticated temperature controlled stores. However, the final value of this technique must be judged by the numbers of farmers who accept and use the technology.

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POTATO BREEDING THROUGH MUTAGENESIS IN APOSPOROUSLY GENERATED TRUE SEED CLONES OF ESTABLISHED VARIETIES

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Summary

Potato varieties which have maintained production during long-term cultivation without renewal from clean seed sources are valuable genetic resources. They possess stable performance in many locales under farmer cultivation practices and seed distribution systems. Genetic improvement of such varieties can best be accomplished by using methods that do not disrupt the basic integrity of the genotype since its complexly inherited overall adaptation and tolerance are worthy of preservation as a unit. Direct early screening on mutagenized progenies could identify mutants that while retaining nearly all the desirable traits of the original, are altered in important key characters. Shortening of the vegetative period and tuber dormancy are two such mutable characters. Mutagenesis is a currently available breeding technology. Mutagenizing single initial cells through use of the adventitious shoot method (van Harten et al., 1981) or hormone-induced apospory as suggested here, could be useful.

Introduction

The acceptance of Mendelian genetics at the turn of the Twentieth Century led to systematic investigations of sexual breeding methods for breeding potatoes. However, not until 1920 was a breeding program publicly funded in the United States, for example (Krantz, 1950). Selection of new varieties from seedlings has permitted the rapid incorporation of resistances to pests and diseases from wild species and native Andean cultivars and has promoted in more recent times an expansion of the genetic base. Sexual breeding methods will undoubtedly continue to be the major source of new varieties in the future. Earlier a few varieties were selected from somatic variants and in 1977 five of these comprised 45% of the North American seed acreage (Thornton and Sieczka, 1980). Selection of somatic mutants permits slight modifications within a complex of preferred characters.

Potato production in developing countries is limited, at least in part, by lack of availability of healthy seed. This has necessitated expensive importation of seed of "adapted" varieties from the developed countries. Importation must be repeated, usually on an annual basis, because the varieties are not resistant or tolerant to tuber-transmitted pathogens which lead to rapid decline in the productivity after several multiplications. Consequently, a major component of the International Potato Center's breeding strategy is the distribution of new clones combining resistance to pests and pathogens with high yielding capacity. The main obstacle to success lies in the low probability of combining resistance, high yield, adaptation to local cropping systems and superior culinary qualities.

Tolerant established varieties. Some established varieties in the developing countries show a complex of resistances and tolerances to biotic and abiotic stresses and maintain production without sophisticated seed programs. They exhibit "tolerance" (Buddenhagen, 1981), i.e. any combination of tolerances or resistances which consistently prevent pathogens from reducing the economic yield. Specifically "... a genotype is more, or it is less tolerant as measured by degree of continued growth and eventual yield when sick..." (Buddenhagen, 1981), or when subjected to major physical environmental stress. Tolerance involves many genes; a difficult complex to recover intact in progenies of a sexual breeding program.

Maintaining intact the essential genotype while modifying certain characters is possible by utilizing mutagenesis. Obtaining offspring whose somatic constitution is solidly mutated is difficult. Instead, chimeras of various sorts frequently occur and mutant genotypes are thought to be lost due to diplontic selection. However, if mutagenesis is induced at a stage where future progenies exist only as single initial cells, chimeras should not occur. In potatoes, mutagenizing in vitro vegetative explants later gives rise to adventitious shoots nonchimeric in composition and apparently derived from single cells (Miedema, 1973; van Harten, et al., 1981).

As judged by end-products, mutagenesis has been relatively unsuccessful in producing new varieties, although one mutant cultivar is now reported (Broertjes and van Harten, 1978, p. 65). Identification of day length neutral mutants (Upadhya et al., 1974) and isolation of wart resistant mutants from the susceptible variety Lorkh (Tarasenko and Kharitonova, 1976) are good examples of success when investigation was conducted with specific objectives.

Mutagenesis is as applied to aposporously generated true seed clones. Obtaining true seed through chemically induced apospory was proposed by Iwanaga and Peloquin (1982) and Iwanaga (1982). Apospory occurs naturally in some angiosperms (Grant, 1971) and apomictic production of true seed by 2,4,D (Irikura, 1981) suggested application of this process in potato.

Przewozny et al. (1980) applied mutagens to premeiotic buds of dihaploid potatoes and subsequently isolated mutant plants through anther culture. This procedure may have produced mutagenized pollen mother cells which later gave rise to solidly mutant diploid homozygous genotypes. Variation in regenerated plants would, therefore, have resulted from mutagenesis and from meiosis. Mutagenesis where apospory is the mode of embryo formation (not involving sporogenesis and meiosis) would provide one advantage where specific improvement of a cultivar is intended, i.e. true seed progeny would be clones of the mother plant (Bashaw, 1980). If mutagens were applied when the future embryo exists as a single cell derived from nucellar tissue, the progeny should be solidly mutated and similar, but not necessarily identical to the parent. Appropriate selection could begin at the seedling stage. The ability to store progenies as true seed would greatly alleviate the practical problems of timing the evaluation of numerous progenies. Transfer of progenies to different locations in the world for evaluation could be conveniently and economically done in the form of true seeds or tuber families with a minimum of quarantine restrictions.

A specific case. The cultivar Conchita grown in the Benguet Province of the Philippines is an example of a tolerant, nondegenerating variety. Introduced around 1960, it has never been renewed by imported seed. It occupies about 40% of the wet season crop (April to November) with yield as good or better than other varieties and it is resistant to late blight and tolerant to high winds, and heavy rains. It is totally virus-infected, possessing a vigorous though chlorotic foliage. As judged by its excellent production it is tolerant to these viruses.

The major undesirable features of Conchita are long tuber dormancy and a long vegetative period of 110 to 130 days (Potts, 1981). Both of these characters are amenable to modification through mutagenesis (Central Potato Research Institute, 1974; Gomez and Estrada, 1972; Nybom, 1961, Porfir'ev, 1974; Roer, 1967; Solonenko, et al., 1971; Surkova, 1973; Umaerus, 1966; Upadhya et al., 1974; Veselovskii and Zaretskii, 1972). A new variety basically Conchita, but with a shorter tuber dormancy and an earlier maturity would be a significant improvement for use in the Philippines.

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INFLUENCE OF PRESTORAGE TREATMENTS ON MARKET QUALITY OF POTATOES

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Abstract

Post harvest/prestorage mechanical handling and chemical treatments influence market quality of potatoes out of extended storage. This paper dwells on the engineering aspects of handling and treatments which drastically alter market quality.

THE VARIABILITY OF ROOT-KNOT NEMATODES AND THE NATURE OF POTATO RESISTANCE TO THESE NEMATODES

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The most convenient, economical, and effective method of controlling root-knot nematodes (Meloidogyne spp.) is the use of resistant cultivars. Research on root-knot resistance in potatoes has primarily involved screening. Some resistant clones were obtained in tests with one population of Meloidogyne spp. but variability of the nematode requires determining the response of resistant clones to other populations and races. Such information is important for the identification of areas where resistant clones can be used.

This research was concerned with five different facets related to resistance of potato to Meloidogyne spp. 1) The reliability of morphological characters and host differential plants in taxonomic identification and relation between morphology and parasitism of two root-knot nematode populations (population A originally from North Carolina and population B, from Georgia). Results indicate that perineal patterns, male head shape, and Sasser's differentials can be used, with limitations, to identify species of Meloidogyne. The number and degree of annule pronunciation, male stylet length, and Golden's differentials are not suitable to distinguish subspecies. Therefore, the synonymy of M. incognita acrita with M. incognita is supported. Race identification with different crops as differentials is rejected and a race scheme for M. incognita on potatoes is proposed.

2) Host efficiency of five clones of Solanum tuberosum ssp. andigena (TA) and seven clones of S. sparsipilum x (S. phureja x S. tuberosum ssp. tuberosum (SPT) for root-knot nematodes was determined. Host efficiency was based on nematode Pf/Pi ratio and number of eggs/g of root. If Pf/Pi was more than 1, the clones were considered efficient hosts. Inoculum consisted of M. incognita populations A and B which were identified as "race 1" and four "races" from the I.M.P. collection. Host efficiency for M. incognita, M. javanica, M. arenaria and M. hapla, based on gall index was also recorded. All TA clones and one SPT clone (D6) were efficient hosts for populations A and B. Four SPT clones (C6, M11, N4 and E2) were non-efficient hosts for both populations. Two SPT clones (H2 and F2) were non-efficient hosts for population B but efficient hosts for population A. This response indicated differences in parasitism on potato between populations of "race 1". This is one of the reasons why a race scheme of M. incognita on potatoes was proposed. All TA clones and one SPT clone (D6) were efficient hosts for the four "races". Six SPT clones were non-efficient hosts for the four "races". No nematode reproduction was obtained except with "race 2". In a second experiment conducted partly in the summer, four clones (H2, E2, N4 and F2) were efficient hosts for "race 2" and clone H2 was an efficient host for "race 1", suggesting that temperature affects resistance. All TA clones were efficient hosts for M. arenaria, M. javanica and M. hapla except clone 1159 which was a non-efficient host for M. hapla. All SPT clones were non-efficient hosts for M. arenaria and M. javanica except clone H2 that was an efficient host for M. javanica. All SPT clones were efficient hosts for M. hapla. In a second experiment conducted mainly in the summer, most of the clones were efficient hosts for the four species.

3) Relation of nematode density to plant damage was studied in rooted cuttings inoculated with M. incognita population B (0, 0.1, 0.5, 1, and 5 eggs/g of soil). At 60 days after inoculation, nematode Pf/Pi ratios were determined. Plant height and root and tuber weights were recorded 60 d. after planting and at harvest. Based on tuber weight at harvest and nematode reproduction at 60 d., TA clones 1B32 and 1037 were tolerant and clones 66 and 1159 were susceptible. Clone 66 had very poor growth and no tuber production. The nematode damage threshold density in clone 1159 was 5 eggs/g of soil. Four SPT clones were inoculated with 0, 1.5, and 10 eggs/g of soil. Plant height 30 d. after inoculation and root, tuber, and foliage weight 60 d. after inoculation were not related to nematode density. Based on tuber weight at harvest and nematode reproduction at 60 d: clones H2, E2, and N4 were resistant and clone D6 was susceptible. Nematode damage threshold density in clone D6 was 10 eggs/g of soil.

4) The nature of potato response to M. incognita race 1 and correlation of root and tuber response were studied in the SPT resistant clones E2 and N4 and the susceptible clone D6. For penetration, histopathology, and nematode development studies, cuttings with root primodia were transplanted to a special tray. This tray allowed the roots to grow horizontally over a sheet of miracloth where the root tips were inoculated. To determine the optimum nematode density, 10, 20 and 30 larvae per root tip were used. Roots examined 12 h. after inoculation indicated 30 larvae/root tip to be the best density. The studies were continued with roots examined at various intervals beginning at 24 h. until 30 d. after inoculation. Clone D6 had a compatible response and was penetrated sooner and by more larvae than were clones E2 and N4 which were incompatible. In some root tips of clones D6 nematode development stopped root growth and the root tip curved. In clone D6, nematode sex was distinguished at d. 12 and the life cycle was completed in 25 d. Some larvae were observed coming out to the roots of incompatible clones. Necrosis appeared at d. 2 in clone N4 and at d. 7 in clone E2. The final response, however, was the same in the two clones. The incompatible response of these two clones was hypersensitive. Both the vermiform L2 and cells around the nematode died. The cells became necrotic and the nematode disintegrated and disappeared. Although root response of compatible and incompatible clones differed, there were no differences in tuber response. Very few L2 penetrated the tubers and none of them developed, even in tubers stored after harvest. Apparently tubers are efficient hosts and show symptoms only in warm climates.

5) Effect of temperature, plant age at inoculation, and origin of plant on host efficiency of potato to M. incognita race 1 was determined in susceptible and re-

sistant clones. This information is important for detecting resistance in a more precise, faster and easier way, planning integrated control strategies, potato adaptation to tropical areas, and for the commercial use of botanical and vegetative seed in potato propagation. For temperature studies the resistant clones E2, N4 and H2 and the susceptible clone D6 were used. Transplanted stem cuttings of these clones were grown in controlled growth chambers at 14, 23, 31 and 35°C, but only inoculated treatments were considered. Low temperatures favored root growth and tuber production. Plant growth was limited at 35°C. Yield parameters did not show nematode effects, but the root systems of inoculated plants were severely damaged at 35°C. At this temperature, some plants were almost dead at harvest and some plants inoculated with "race 2" died. All clones became efficient hosts at 31°C except clones F2 and N4 that became efficient hosts at 35°C. The equilibrium density of the nematode differed among clones; being highest with clone E2. Quantitative differences among nematode populations also existed. "Race 2" was more aggressive and reproduced under a wider temperature range than did other populations.

For plant age studies, rooted cuttings (15, 10 and 5 days old) of clones E2, N4 and D6 were inoculated and grown in a greenhouse (23-35°C). Plant age at inoculation did not affect plant growth or host efficiency of the resistant clones. However, root weights were significantly reduced (5%) in younger plants of the susceptible clone. Nematode Pf was higher in plants inoculated when 15 and 10 days old and number of eggs/g of root was higher in plants inoculated when 10 days old.

To study effects of origin of plant on host response, the same clones as for plant age studies and seed from families E802 and C251 were used. Growth differences between plants of different origins (tubers, stem cuttings and true seed) were significant. Tubers were produced only in plants originating from cuttings. Lowest yield parameters were obtained with plants from seed. The nematode did not significantly affect plant growth regardless of origin. However, nematode reproduction was greatly affected in the susceptible plants. Nematode PF was significantly higher on plants from cuttings and the number of eggs/g of root was higher in plants from seed.

THE POTATO NATIONAL TRIALS AND THEIR INFLUENCE ON SEED IMPORTATION IN BRAZIL

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Potato is a crop which had a 51% increase in Brazil during the last 10 years. The national yield average of 10.6 t/ha is still very low in comparison to the average yields of many other countries. Among the inputs that affected productivity, better varieties and better seed quality were the principal ones.

Brazil is importing around 12,000 to 15,000 tons of potato seed per year, from Holland, Germany, and Sweden mainly. This potato seed is multiplied with different levels of technology to produce the 240,000 tons needed for planting at present time. More productive varieties are needed to decrease production costs and permit a larger use of the potato by the less wealthier part of the population.

Materials and methods

Potato varieties are submitted to two types of tests: The First Evaluation Test, for all new varieties and the Advanced Tests for the ones selected in the previous test.

The First Evaluation Tests are carried out in five locations under different climatic conditions of the South, Southeast, West and Northeast of Brazil. The Advanced Tests are conducted in 14 locations in areas of commercial production, representing 12 states in four of the five geographic regions of Brazil. The plants receive 2 t/ha of a 4-14-8 fertilizer mixture plus 300 kg/ha of an ammonium sulfate at the ridging time. Insect and disease control are done as needed in different locations. Data for vigor, disease and insect damage, life cycle and production are recorded.

Results and discussion

The results obtained in the last 4 years show that yield can be increased with varieties that are better adapted to the different planting regions (Table 1). More productive varieties were generally more resistant to foliage diseases and more efficient in nutrient uptake under lower fertilizer application conditions. The most popular varieties Bintje, Achat, Delta S, and J. Bintje, produced average yields of 14.6, 13.0, 15.6 and 16.7 t/ha, respectively. Imported varieties that are becoming more popular are Recent, Baraka, Radosa, and Marijke, which yielded averages of 22.4, 18.5, 17.7 and 17.5 t/ha, respectively.

New Brazilian varieties - Mantiqueira, Mineira and Chiquita and older ones - Aracy, Baronesa and Santo Amor - were among the highest yielders, with general average yields varying from 18.3 to 23.1 t/ha.

Table 1. Summary of the potato national trials of Brazil, February 1977 to August 1980.

Cultivar	Origin	South Region Yield 1/	Southeast Region Yield	Northeast Region Yield	West Region Yield	Total Average Yield
MANTEQUEIRA	BRAZIL	-	22.8/2	18.8/4	29.1/3	23.1/9
RECENT	HOLLAND	12.4/2	25.3/7	19.0/3	25.0/4	22.4/16
MINEIRA	BRAZIL	-	20.1/2	16.9/4	24.4/3	20.1/9
SPUNTA	HOLLAND	16.8/10	18.3/14	13.4/5	33.4/6	19.8/35
ARACY	BRAZIL	5.5/1	21.8/8	15.1/6	25.2/4	19.5/19
BARONESA	BRAZIL	14.2/1	19.3/7	19.7/4	20.2/5	19.4/17
CHIQUITA	BRAZIL	-	20.3/2	11.7/4	27.5/3	18.9/9
BARAKA	HOLLAND	15.5/10	17.3/14	14.6/6	26.3/9	18.5/39
SANTO AMOR	BRAZIL	8.2/2	15.9/6	16.8/3	26.1/5	18.3/16
NICOLA	HOLLAND	14.5/3	20.0/7	13.2/4	20.8/8	18.3/22
DESIRÉE	SCOTLAND	14.7/3	16.9/5	9.9/1	26.5/3	18.2/12
ESTIMA	HOLLAND	15.5/10	18.0/14	12.1/6	23.9/10	18.0/40
RADOSA	HOLLAND	16.7/10	18.1/16	12.2/6	21.3/10	17.7/42
MARIJKE	HOLLAND	16.1/10	16.7/14	11.0/6	24.1/10	17.5/40
BELLADONNA	GERMANY	16.5/6	17.9/14	12.0/3	19.4/8	17.4/31
ATICA	GERMANY	16.6/3	18.4/4	-	15.6/1	17.3/8
NORDSTERN	GERMANY	16.5/6	17.9/13	14.8/3	17.3/8	17.2/30
UNIVITA	GERMANY	18.0/6	18.9/13	11.2/3	16.0/8	17.2/30
EDZINA	HOLLAND	12.1/2	18.3/7	13.9/3	18.3/4	16.7/16
J. BINTJE	SWEDEN	20.1/9	14.2/17	12.4/6	21.0/9	16.7/41
VITORINNI	HOLLAND	9.3/2	22.1/6	10.8/4	17.5/8	16.7/20
GRANOLA	GERMANY	16.6/5	17.5/8	-	15.3/4	16.7/17
PALMA	GERMANY	15.8/14	16.6/20	8.3/4	21.4/10	16.7/48
PATRONES	HOLLAND	15.1/10	15.9/14	12.8/6	21.6/8	16.4/38
ULLA	GERMANY	18.5/9	13.9/8	7.3/3	21.3/4	16.0/24
GELDA	GERMANY	15.6/7	15.4/8	7.7/3	26.4/3	15.9/21
DELTA S	SWEDEN	10.7/2	15.8/7	16.9/3	16.3/7	15.6/19
GRANDIFOLIA	GERMANY	13.0/16	15.9/26	7.2/6	19.9/12	15.6/60
OMEGA	GERMANY	15.2/12	15.5/16	5.1/4	20.2/8	15.3/40
ELVIRA	HOLLAND	12.0/2	18.7/7	8.3/3	15.0/3	15.0/15
BINTJE	HOLLAND	13.9/12	14.2/22	10.2/9	18.8/14	14.6/57
LINDA	GERMANY	12.8/6	16.8/11	6.7/6	19.8/6	14.5/29
ACHAT	GERMANY	12.3/16	13.7/27	5.3/5	16.0/10	13.0/58
HYDRA	GERMANY	7.3/3	16.5/5	-	7.9/1	12.5/9
PORTA	GERMANY	-	-	-	9.9/3	9.9/3
VOKAL	HOLLAND	-	27.5/2	-	-	-
Weighed average		14.2	17.1	11.9	20.9	

1/ Average yield in tons per ha/number of tests.

The average yields obtained in new planting areas of the western region show their greater potential due to temperatures and dry weather that prevails during the winter months. This is true if proper soil corrections and irrigation levels are given to the potato plants in this region.

CONTROLLING A PREMATURE DEATH OF RUSSET BURBANK POTATOES WITH FOLIAR APPLICATIONS OF PROCHLORAZ

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If worldwide potato yields are to be increased by the year 2000, a greater understanding of diseases of senescence and stress will be required. Recent investigations with prochloraz (a broad spectrum fungicide) indicate the potential of this material for the investigation of an unidentified form of 'premature' death of potato. To date, Colletotrichum atramentarium (Syn C. coccodes) is the only recognized pathogen to be consistently associated with this disease. For 3 consecutive years foliage sprays with prochloraz have suppressed the death of potatoes and for 2 out of 3 years these treatments have significantly increased yields by 20 to 25%. Results demonstrate the capacity of foliar treatments with prochloraz to suppress the colonization in potato stem tissue by a soilborne pathogen (C. atramentarium--causal organism of the black dot disease of potato).

Introduction

During the growing season of 1979 a variety of foliage fungicides were applied to Russet Burbank plots for screening pesticides against the early blight disease (Alternaria solani) of potato (Solanum tuberosum). Among these treatments, prochloraz was included. The effect of prochloraz treatments on potato senescence and necrosis was definitive. Plants in treated plots remained green through the last week of September while those in untreated plots and plots treated with several other fungicides were dead. With this suppression of 'premature' death, potato yield, specific gravity, and tuber size were significantly (.05 P) increased. The only known pathogen that could be consistently associated with this problem was Colletotrichum atramentarium). Stem tissue from plots treated with prochloraz was colonized significantly (.05 P) less by this fungus than from those not treated. The black dot disease (caused by C. atramentarium) is common in many areas of the world, but the relative importance of this problem has not been well documented (Davis, 1981).

Prochloraz is a complex imidazole that has a high level of activity against a wide range of plant pathogens. It is particularly active against Ascomycetes and Fungi Imperfecti, while control of the Basidiomycetes and many of the Phycomycetes appears to be of a lower order. This compound possesses no recognized effect against bacteria. Further studies with prochloraz were continued in 1980 and 1981 to determine if the effects on premature death were consistent, to investigate the causal nature of the problem, and to relate results to potato yield and quality.

Materials and Methods

Field studies using prochloraz and cv. Russet Burbank were conducted and included rate studies with foliar sprays (0.30 to 1.12 kg/ha a.i.), different numbers of foliage sprays throughout growing season (1 to 5), and a comparison of soil treatment (5.6 kg/ha a.i. incorporated in uppermost 12.5 cm of soil) with foliar treatments. Comparisons were made between prochloraz and a range of fungicides that were foliage applied at recommended rates (e.g. maneb, vinclozolin, and chlorothalonil). An additional study also included A68113-4 -- a potato clone known to be highly resistant to Verticillium dahliae. Isolations were made on a variety of artificial media from roots and stems collected from field plots. Replicated assays were made from plots each year for Verticillium dahliae and C. atramentarium using a previously described method (Davis et al., 1977). Isolates of C. atramentrium were routinely cultured onto a selective medium (Farley, 1972) for further identification.

Results

Field studies of 1980 and 1981 corroborated the initial observations of 1979. Foliar spray treatments with prochloraz at 1.12 kg/ha a.i./spray (5 sprays during the season) were found to consistently suppress the 'premature death' of potato. Similar disease suppression and yield benefits occurred when prochloraz was applied 5 times at 0.3 kg/ha a.i./spray. Table 1 demonstrates the effect of different numbers of spray treatments upon disease suppression. Results show significant (.05 P) reduction of disease when treatments included both early and late sprays. No indication of a benefit was evident when prochloraz was applied as a preplant treatment to soil. Stem assays for V. dahliae from treated and untreated plots show no relationship between this pathogen and the unknown condition. This observation is further supported by the fact that prochloraz (at 1.12 kg/ha a.i./spray-5 sprays during growing season) was also effective for suppressing the 'premature' death of A68113-4-- a potato clone providing a high level of resistance to V. dahliae. In contrast, prochloraz treatments (5 sprays at 1.12 kg/ha a.i./spray) have consistently suppressed the colonization of C. atramentarium in potato stem tissue. Figure 1 demonstrates this effect on the Russet Burbank cultivar. This same relationship has also been observed for A68113-4. Isolation data and efficacy studies with other fungicides have provided no evidence for the consistent relationship of another known pathogen. Among plots treated with 5 foliar sprays of prochloraz with rates ranging from 0.30 to 1.12 kg/ha a.i./spray, studies have either consistently suggested trends towards yield increase or demonstrated significant yield benefits over untreated plots that have ranged from 20 to 25%.

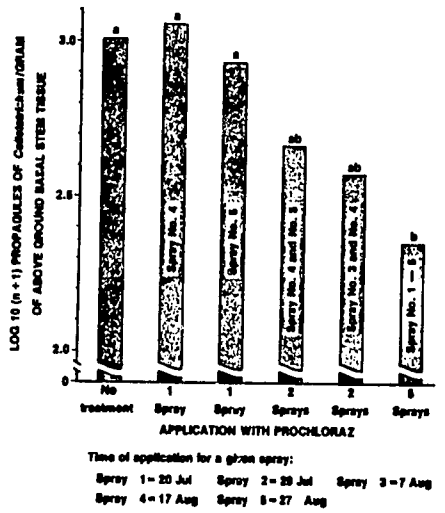

Figure 1. Influence of prochloraz on colonization of Collectotrichum atramentarium in potato.

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Table 1. Influence of Prochloraz treatments on the premature death of Russet Burbank potato.

Treatment	Indices[1/] of premature death incidence on given dates			
	9-11-81	9-18-81	9-23-81	9-28-81
No treatment	2.8 A[3/]	5.0 A[3/]	8.4 A[3/]	9.0 A[3/]
1 spray (No. 4)[2/]	1.2 CD	2.8 BCD	5.0 C	5.0 CD
1 spray No. 5)	2.0 B	3.2 B	7.0 AB	7.2 B
2 sprays (No. 4 & 5)	1.8 BC	3.0 BC	4.4 CD	4.4 CDE
2 sprays (No. 3 & 4)	1.0 D	2.8 BCD	5.6 BC	5.6 C
5 sprays (No. 1-5)	1.4 BCD	1.8 D	3.0 D	3.0 E

1/ Higher values indicate increased incidence of death (0 = no disease expression; 9 = 95-100% plant death in plots).

2/ All treated plots sprayed with Prochloraz. Each spray applied at 1.12 kg/ha a.i. Times of application for given sprays: No. 1-20 July; No. 2-29 July; No. 3-7 Aug.; No. 4-17 Aug.; No. 5-27 Aug.

3/ Different letters denote significant differences by Duncan's multiple range test (.05 P).

DEVELOPMENT OF NEW POTATO CULTIVARS WITH HIGH VERTICILLIUM RESISTANCE AND INCREASED YIELD POTENTIAL BY THE YEAR 2000

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If new yield levels are to be reached for worldwide potato production by the year 2000, resistance to Verticillium wilt will be necessary. Greenhouse and field investigations indicate recently developed potato clones A66107(-51) and A68113(-4) to have a high level of resistance for Verticillium dahliae. These resistant clones have maintained resistance to V. dahliae for a four year period of cropping while simultaneously maintaining acceptable quality and higher yields than more susceptible potatoes (Russet Burbank and Butte).

Introduction

Verticillium wilt (Verticillium dahliae Kleb.) of potato (Solanum tuberosum L.) is recognized as a major limiting factor to production in several areas of the world including the U.S.A. Because of this, a considerable portion of our efforts has been directed towards the development of potato cultivars with high degrees of resistance to Verticillium wilt. Although several workers (Akeley et al., 1971, Isaac and Harrison, 1968, Susnochi et al., 1976, Krinkun and Orion, 1979) have reported field resistance, no reports can be found that document levels of Verticillium colonization accompanying resistance. Since symptoms of Verticillium wilt of potato may not always be reliable for accurate diagnosis (Isaac and Harrison, 1968) the degree of Verticillium colonization in potato tissue must be taken into account if either tolerance or resistance to Verticillium spp. is to be truly evaluated. Also lacking in the literature are data describing stability of Verticillium resistance with continuous cropping of potato. With the clones included in our study, we have attempted to answer these questions while relating results to yield and quality.

Materials and methods

Five potato clones were evaluated in the greenhouse for V. dahliae resistance by replicated root dip inoculations of 10^7 prop/ml of two V. dahliae isolates. Resistant potato clones were compared with commonly grown susceptible cultivars by continuously cropping for four consecutive years in replicated, naturally-infested, field plots. Throughout this study V. dahliae colonization in potato stems and survival in soil were determined using previously described methods (Davis et al., 1977; Butterfield and De Vay, 1977). Results were related to potato yield.

Results

Greenhouse studies indicated that clones with high field resistance to V. dahliae (A66107-51 and A68113-4) were also resistant to colonization by the pathogen. Symptom expression and V. dahliae colonization in potato petioles were significantly lower in the resistant clones than in either Russet Burbank (RB) or Butte (B). Verticillium dahliae propagules/gm of petiole tissue correlated highly (.001 P) with symptom expression and with ratios of total yield for inoculated/non-inoculated plants for each clone. With increased resistance, yields were higher. Similarly, when these same clones were grown continuously for four consecutive years in the same respective field plots, they have consistently displayed significantly less wilt symptoms (Figure 1) and significantly less colonization (Figure 2) by V. dahliae in apical stem tissue than the susceptible cultivars (RB and B). Each year, the wilt severity for either -51 or -4 has remained negligible (1.0%). In contrast, relative wilt severities for either RB or B have consistently exceeded 39% by late August. These data are further corroborated by symptoms of vascular discoloration and V. dahliae colonization at base of stems. Throughout these four years of cropping, foliage wilt symptoms,

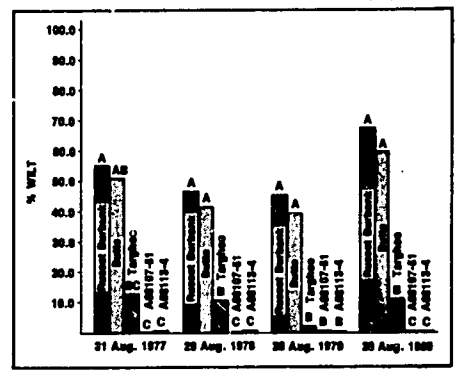

Figure 1. Relative Verticillium wilt severity among potato cultivars with continuous cropping.

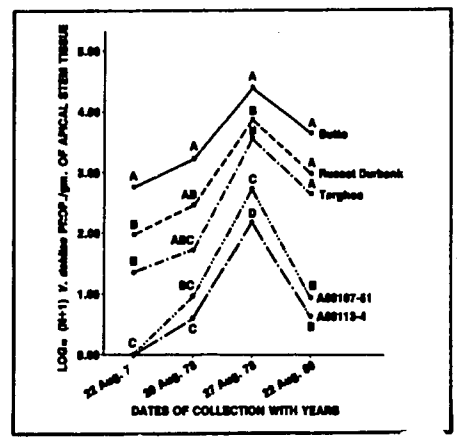

Figure 2. Relative Verticillium dahliae colonization of apical stem tissue among potato cultivars with continuous cropping.

vascular discoloration, and V. dahliae colonization for Targhee (T) have generally been between the susceptible and resistant extremes. With continuous cropping, clones with highest field resistance (-51 and -4) have maintained the highest yields along with acceptable quality. Yields with -51 have ranged from 28 to 110% higher than RB while yield increases with -4 have ranged from 38 to 142% higher (.05 P significance). The percent of root infection by V. dahliae was significantly (.05 P) less with -51 than with either RB or B. Although the same trend for less root infection existed for T and -4, differences were not significant.

Results further suggest decreases in V. dahliae soil populations that are related to clonal resistance. After two and three respective years of continuous cropping, V. dahliae populations in soil (sampled annually prior to planting) consistently correlated (.01 P) with wilt symptoms among all clones (R^2 = 0.37 for each consecutive year). After two years of cropping, V. dahliae soil populations were lower (0.05 P) in plots where either T, -51, or -4 were grown than in plots where RB was grown.

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NEW POTATO SPINDLE TUBER TEST: IMPLICATIONS FOR THE FUTURE

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Introduction

Several plant diseases that are now known to be viroid-incited are of considerable economic importance (reviewed by Diener, 1979). Although at least one viroid, the potato spindle tuber viroid (PSTV), can be eliminated from infected plants by cold treatment and meristem culture (Lizárraga et al., 1980), most control measures are based on prevention rather than cure, thus necessitating reliable and sensitive methods for their detection in plant stock. Viroids lack the antigenic protein coat characteristic of viruses; they therefore pose a problem in diagnosis. Not surprisingly, assays based on immunological principles, such as the sensitive and widely used ELISA (enzyme-linked immunosorbent assay) technique have not been reported. Two types of diagnostic test have been used to detect PSTV: bioassay

on suitable tomato cultivars (Raymer ar. O'Brien, 1962; Fernow, 1967) and polyacrylamide gel electrophoresis (PAGE) of extracted nucleic acids (for example Morris and Wright, 1975). Although Fernow et al. (1969) have demonstrated that a double-inoculation technique can be used to detect both mild and severe strains of PSTV from potato seed stocks, bioassays on tomato are slow and unreliable under certain environmental conditions. Detection by PAGE, on the other hand, is laborious and expensive. Neither method is suitable for the rapid screening of thousands of seed potato tubers.

One possible alternative is hybridization of highly radioactive DNA complementary to PSTV (PSTV cDNA) with PSTV bound to a solid support, and autoradiographic detection of the resulting DNA-RNA hybrids. Hybridization in solution has already been used to detect the presence of viroids in purified RNA preparation (Owens et al., 1978; Palukaitis et al., 1979). Two conditions had to be fulfilled before hybridization with PSTV cDNA could be developed into a practical diagnostic test for the detection of PSTV in numerous samples: (1) PSTV cDNA had to be available in unlimited quantities and at high specific radioactivity, requiring cloning of the cDNA by recombinant DNA technology and nick-translation of the DNA; and (2) to expedite and simplify sample preparation, clarified sap rather than purified nucleic acid had to be suitable as the viroid source. Both conditions have been fulfilled and a practical diagnostic test for the detection of PSTV based on nucleic acid hybridization has been developed (Owens and Diener, 1981).

In this paper, we first describe the new nucleic acid spot hybridization method, then present evidence of its sensitivity, specificity, and reliability, and finally examine the potential impact of the novel diagnostic method on practical agriculture - on commercial potato production and in its application to viroid-incited diseases of other crops. Finally, we consider possible uses of similar spot hybridization procedures for purposes other than viroid detection.

Molecular cloning of PSTV cDNA

Determination of the 359 nucleotide sequence of PSTV established viroids as the first naturally occuring examples of covalently closed circular RNA (Gross et al., 1978). The molecular cloning and characterization of double-stranded (ds) PSTV cDNA (Owens and Cress, 1980) has been facilitated by knowledge of the RNA sequence. In the latter work, ds PSTV cDNA was synthesized from a polyadenylated linear PSTV template and inserted in the PstI endonuclease site of plasmid pBR322 using the oligo (dC) · oligo(dG) tailing procedure. Although one recombinant clone (pDC-29) contained a larger than expected 460 base-pair (bp) insert, restriction endonuclease mapping and nucleotide sequence determinations showed that all recombinants contained less than a complete copy of PSTV. Figure 1 shows the strategy used to construct clones containing full-length dsPSTV cDNA.

Restriction analysis of the PSTV-specific inserts from two of these clones, pDC-22, suggested that these clones were partially overlapping and could be used to construct a full-length clone. The 285 bp AvaII-HaeIII fragment from pDC-22 was ligated at

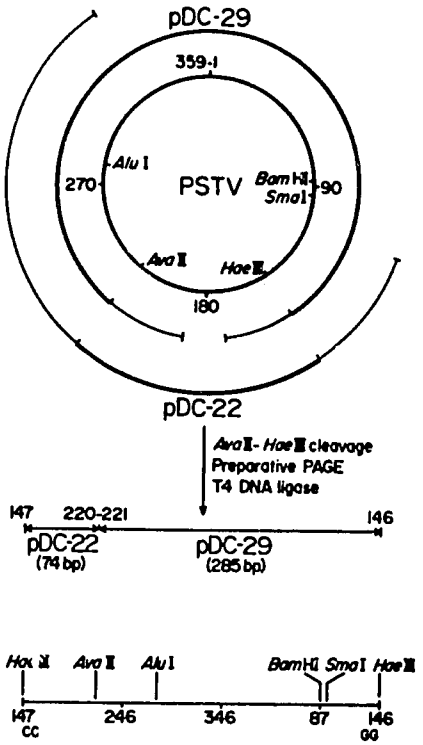

Figure 1. Construction and molecular cloning of full-length dsPSTV cDNA.

the AvaII site to the contiguous 74 bp AvaII-HaeIII fragment from pDC-22. HindIII oligodeoxynucleotide linkers were added to the HaeIII blunt ends of this linear ligation product and, following digestion with HindIII, this fragment was cloned in the HindIII site of pBR322. HindIII digestion of the resulting clones released the expected 365 bp PSTV-specific fragment.

Because use of this particular HindIII decanucleotide linker reconstructed the terminal HaeIII sites of the PSTV insert, digestion of the recombinant DNA with HaeIII relases a 359 bp fragment. This fragment is full-length dsPSTV cDNA. Determination of the complete nucleotide sequence of this DNA by a combination of the Maxam-Gilbert chemical degradation and M13 dideoxy chain termination methodologies has shown the cloned DNA sequence to be identical with that predicted by the published RNA sequence.

PSTV diagnosis by nucleic acid hybridization

Figure 2 summarizes the sample preparation and test procedure used.

A relative high ionic strength and diethyldithiocarbamate concentration of the extraction buffer serve to release PSTV from nuclei and inhibit enzymatic polyphenol oxidation, respectively. Each sprout or seed sample (0.1 to 0.2 g) is homogenized at room temperature in a small conical groundglass homogenizer in the extraction buffer shown (1.5 ml per gram of tissue or 0.2 ml per 16 true seeds). Tissue debris is removed by brief low-speed centrifugation, and the sap is used immediately. Three-to five- µl portions of the sap samples to be tested are then pipetted onto a treated nitrocellulose membrane (Thomas, 1980) which was baked as indicated in Figure 2. Although RNA covalently binds to diazobenzyloxymethyl (DBM) paper (Alwine et al., 1979), this support is expensive and requires a number of carefully controlled steps to prepare and use. Because RNA also stably binds to a nitrocellulose membrane (Thomas, 1980), and because this method is simple, inexpensive, and reproducible, nitrocellulose rather than DBM paper is used.

Hybridization reactions are performed essentially as described (Wahl et al., 1979), but we have found that the prehybridization reaction can be omitted. The same buffer [40 percent (v/v) formamide, 0.18M NaCl, 10mM sodium cacodylate, 1mM EDTA, 0.1 percent sodium dodecyl sulfate, and yeast transfer RNA (400 µg/ml) at pH 7.0] is used for both hybridization and briefly wetting the membrane (5-10 min at 20-25°C) before hybridization. The hybridization reaction is performed for 24 hr at 55°C in the presence of 10 percent dextran sulfate and ^{32}P-labeled nick-translated recombinant PSTV cDNA (1 to 2.5 x 10^6 cpm/ml). The ratio of buffer volume to membrane area is at least 1 ml per 35 cm^2. Nick-translated DNA is denatured by heating for 2 min at 100°C in the presence of 50 percent formamide before addition to the hybridization reaction. Nitrocellulose membranes are washed at 55°C with five changes of 0.36M NaCl, 10mM tris-HCl (pH 7.5) and 0.1 percent sodium dodecyl sulfate and then with two changes of the same buffer diluted tenfold. Autoradiography is carried out for 24 to 48 hr at -70°C with Kodak X-Omat film* and Dupont Cronex Lightning-Plus Intensifying Screens.

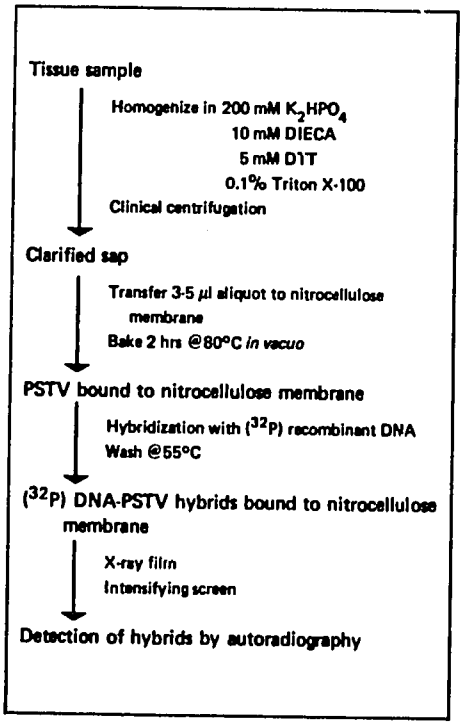

Figure 2. Outline of nucleic acid hybrization procedure. DIECA, diethyldithiocarbamate; DTT, dithiothreitol.

* Mention of a commercial company or specific equipment does not constitute its endorsement by the U.S. Department of Agriculture or CIP over similar equipment or companies not named.

Evaluation of nucleic acid spot hybridization test

Tuber sprouts from commercial varieties

The feasibility and reliability of this method for the rapid and sensitive detection of PSTV by nucleic acid hybridization was demonstrated with tubers harvested from commercial important U.S. potato varieties that had been intentionally infected with PSTV (Owens and Diener, 1981).

Figure 3 shows that PSTV stably binds to either DBM paper or nitrocellulose membrane (rows A to D). Comparison of relative autoradiographic intensities shows that the presence of sap from uninfected tuber sprouts reduces the binding approximately tenfold, but 83 to 250 pg of PSTV are still easily detected after hybridization with radioactive recombinant DNA. This amount is equivalent to a concentration of 0.04 to 0.125 µg of PSTV per gram of tuber sprouts. Actively growing potato tissue contains ≥0.5 µg of PSTV per gram of tissue (Morris and Wright, 1975). Our hybridization method is therefore adequate to detect PSTV in potato tissue. The relatively high ionic strength and diethyldithiocarbamate concentration of the extraction buffer required to release PSTV from nuclei and inhibit enzymatic polyphenol oxidation do not interfere with PSTV binding to nitrocellulose (Figure 3, rows E to G).

No reaction was detected with sap prepared from healthy tubers of six commercial varieties (Figure 4, row B). Sap samples prepared from sprouts of individual PSTV-infected tubers of a given variety contain similar concentrations of PSTV (Figure 4, rows C and D). Finally, the three portions of tuber tested -- sprouts, axillary buds ("eyes"), and the epidermis between the axillary buds -- all contain detectable concentrations of PSTV (≥0.08 µg of PSTV per gram of tissue) (Figure 4, rows E and F).

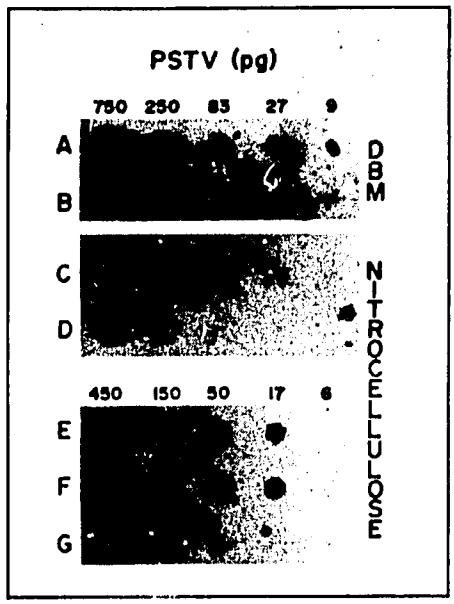

Figure 3. Sensitivity of PSTV detection by hybridization and autoradiography after binding to DBM paper and nitrocellulose membranes. Low molecular weight RNA containing 0.4 to 0.5 percent PSTV was isolated from PSTV-infected tomato seedlings and diluted with a mixture of 0.15M sodium acetate and 0.85M acetic acid (rows A and C), sap prepared from healthy Katahdin sprouts (rows B, D, and G), water (row E), or homogenization buffer (row F). Portions of successive threefold dilutions were then transferred to DBM paper (rows A and B) or nitrocellulose membranes (rows C to G).

Tuber sprouts from CIP clones

Tubers from 20 potato clones currently under investigation at CIP were selected for testing by nucleic acid hybridization at Beltsville. Most of the selections had been tested at CIP by PAGE, but the results of these analyses were not revealed to us at the Beltsville Agricultural Research Center (BARC) until the spot hybridization tests had been completed.

Table 1 shows that of the 20 CIP clones selected, PAGE analysis of nucleic acid extracts from tuber sprouts and/or foliage had disclosed PSTV in 10 clones. One clone had not been tested at CIP, and the remaining clones had given negative results. In contrast to PAGE analysis, nucleic acid hybridization with tuber sprout extracts gave positive results with 17 clones, a weakly positive result with 1 clone, and negative results with only 2 clones.

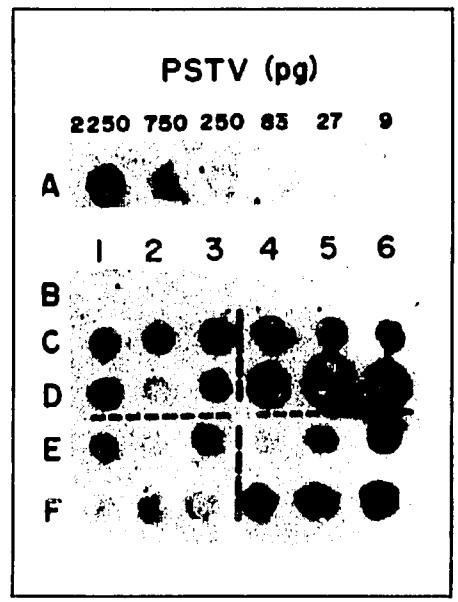

Figure 4. Reliability of PSTV detection by hybridization and autoradiography after binding to nitrocellulose membrane. (Row A) Successive threefold dilutions of low molecular weight RNA containing PSTV that was diluted with sap prepared from healthy Katahdin sprouts; the sample in the first column did not contain sap. (Row B, left to right) Composite sap samples prepared from sprouts taken from several healthy Chieftain, Irish Cobbler, Green Mountain, Katahdin, Kennebec, and Saco tubers. (Rows C and D) Sap samples prepared from sprouts taken from individual PSTV-infected tubers: row C, columns 1 to 3 from Katahdin, columns 4 to 6 from Kennebec; row D, columns 1 to 3 from Saco, columns 4 to 6 from Katahdin line 235. (Rows E and F) Composite sap samples, each prepared from tissue taken from three individual PSTV-infected tubers: columns 1 and 4, epidermis from between eyes; columns 2 and 5, barely sprouted eyes (≤2 mm); columns 3 and 6, sprouts (≥5 mm). Row E, columns 1 to 3 from Katahdin, columns 4 to 6 from Kennebec; row F, columns 1 to 3 from Saco, columns 4 to 6 from Katahdin line 235.

As expected, all clones that had tested positive by PAGE, also tested positive by nucleic acid hybridization. Surprisingly, however, 8 additional clones tested positive in the spot hybridization test. The question thus arose, whether these additional positive results were due to false positive reactions or to increased sensitivity of the spot hybridization test as compared with PAGE.

To reevaluate these initial results, tubers from clones that had given negative or contradictory results were bioassayed on tomato plants. As shown in Table 2, tomato plants that were inoculated with extracts from the 7 clones that had tested definitely positive developed symptoms. Symptoms were either mild or severe (Figure 5), presumably indicating infection by mild or severe PSTV strains, respectively. In all cases, the presence of PSTV in plants with symptoms was confirmed by nucleic acid spot hybridization tests (Table 2).

Reevaluation of the two clones that had tested negative both by PAGE and by spot hybridization (BR 63.15 II and PSP 5.6) was complicated by loss of the tested tuber (T-1) of the latter clone. Bioassay with tissue from sprouts of a second tuber (T-2) from the same clone, however, resulted in severe symptoms in tomato (Table 2, Figure 5); presence of PSTV in the assay plants could be confirmed both by PAGE analysis and spot hybridization. Furthermore, hybridization analysis of a sprout extract from tuber T-2 showed that the tuber was infected.

We concluded that, in some cases at least, PSTV is unevenly distributed in plants, being present in some but not all tubers of the same clone. To test this hypothesis, sprouts from the originally tested, as well as from a second tuber of the other clone that had tested negative (BR 63.15 II) were assayed. In confirmation of the earlier results, the original tuber (T-1) tested negative by bioassay; and both PAGE and hybridization analyses with extracts from the assay plants showed that they were not infected (Table 2). Bioassay of sprouts from the second tuber (T-2), however, resulted in the development of mild symptoms; analysis by both PAGE and spot hybridization of the assay plants confirmed the presence of PSTV. Also, spot hybridization with a sprout extract from tuber T-2 demonstrated the presence of PSTV in the tuber itself (Table 2).

Reevaluation of the tuber from the clone (MB 15.25II) that had given a weakly positive reaction in the original hybridization test (Table 1) failed to demonstrate that the tuber was infected. No symptoms developed in the assay plants and spot hybridization with extracts from the assay plants gave negative results (Table 2).

Table 1. Detection of PSTV in CIP potato clones by PAGE and nucleic acid hybridization.

Clone	PAGE[a]		cDNA[b]
	Foliage	Tuber sprouts	
BR 62.3	-[c]	+	+
BR 70.126	+		+
BR 69.92 II	+	+	+
BR 63.15 I	-	-	+
BR 63.15 II	-	-	-
MB 6.11	+	+	+
MB 34.47 I	+	-	+
MB 40.11	+		+
MB 6.42	-		+
MB 6.1	-	-	+
MB 30.2	-	-	+
MB 34.97 1	-	-	+
MB 34.47 II	+	-	+
MB 5.39 II	+	+	+
MB 15.25 II	-	-	±
MS 117.36	-	-	+
PSY 89.43			+
PSY 104.33	+	+	+
PSW 98.85 I	+	+	+
PSP 5.6	-	-	-

[a] Analysis by polyacrylamide gel electrophoresis performed at CIP.

[b] Analysis by nucleic acid hybridization performed at BARC.

[c] - = negative, + = positive, ± = weakly positive result.

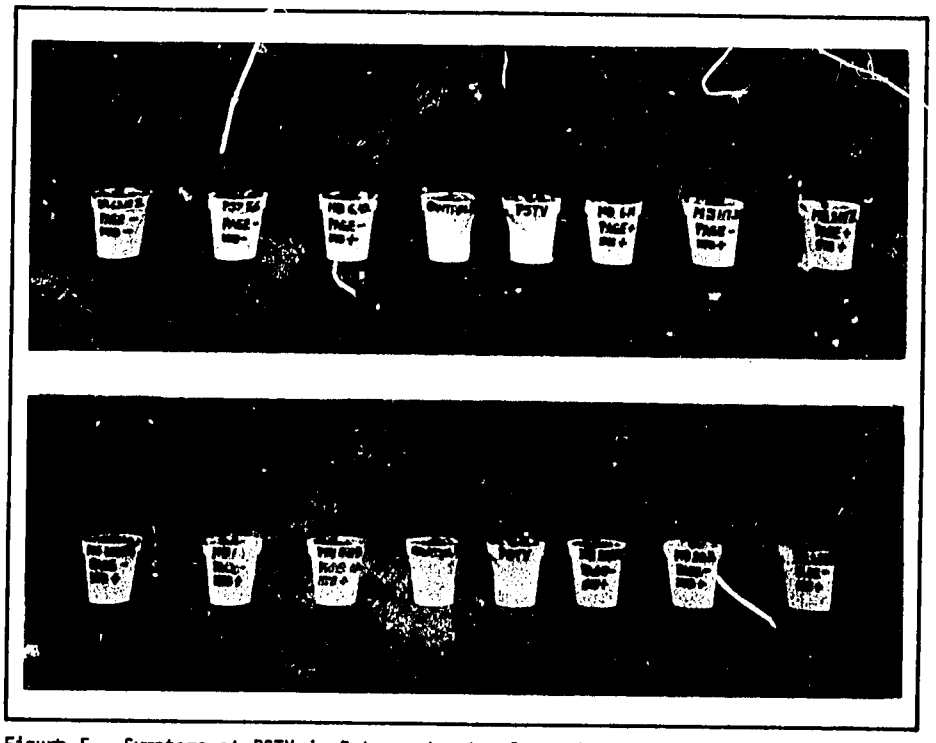

Figure 5. Symptoms of PSTV in Rutgers tomato plants inoculated with tuber sprout extracts from 12 CIP potato clones (pots 1-3 and 6-8 from left, upper and lower rows) or inoculated with purified PSTV (severe strain) (pots 5 of either row). Fourth pot in either row is an uninoculated control.

True potato seed

Major efforts are underway to propagate potatoes by true seed (Upadhya, 1979). Because PSTV is both seed and pollen transmitted (Fernow et al., 1970), it is important to ascertain that seed is free of PSTV. Ideally, a test to be used for this purpose should be sensitive enough to detect PSTV in a composite seed sample, if only one or a few percent of the seeds in the sample are infected. To test whether the nucleic acid spot hybridization test is suitable for this purpose, true seeds were collected from potato plants known to be free of PSTV and from other known to be infected. Seeds from healthy and infected plants were allowed to imbibe water, were mixed in various proportions, and were then homogenized in extraction buffer (see above).

As shown in Table 3, conventional diagnosis by bioassay on tomato failed to detect PSTV in any of the composite samples, even in the one that consisted of seeds from infected plants only. Although none of the inoculated tomato plants showed symptoms, PAGE analysis of extracted nucleic acid demonstrated that PSTV was present in those tomato plants that had been inoculated with seed extracts of samples containing at least 25 percent seeds from PSTV-infected potato plants (Table 3).

Other portions of the composite seed samples were analyzed by the nucleic acid spot hybridization test. Table 3 shows that positive results were obtained with all but one of the samples containing seed from infected potato plants, the sample in which the ratio of seed from infected to seed from healthy plants was 2/14. It is possible that the two seeds chosen did not contain PSTV, because seed transmission of PSTV from open pollinated female parents may vary from zero to 100 percent in individual collections (Fernow et al., 1970).

A more precise estimate of the sensitivity of PSTV detection in seed extracts was obtained by serially diluting an extract of seeds from infected plants with an extract of seed from healthy plants. Figure 6 shows that nucleic acid hybridization can detect PSTV in a extract equivalent to a sample containing one seed from an infected plant plus 80 seeds from healthy plants. Comparison of the spots in row 2 with those in row 4 indicates that sample deproteinization increases the sensitivity approximately three-fold.

Conclusions

Our data demonstrate that the nucleic acid spot hybridization test reliably detects both severe and mild strains of PSTV in crude extracts from tuber sprouts. The test is specific and rarely, if ever, results in false positive indications.

The spot hybridization test is also suitable to detect PSTV in true potato seed. In composite samples consisting of seeds from both PSTV-infected and healthy potato plants, PSTV could be detected when as few as one of 81 seeds had originated from an infected plant. In view of our limited efforts with true seed testing it appears likely that further work may result in detection of still lower levels of PSTV.

The nucleic acid spot hybridization test is about 10 times as sensitive as PAGE.

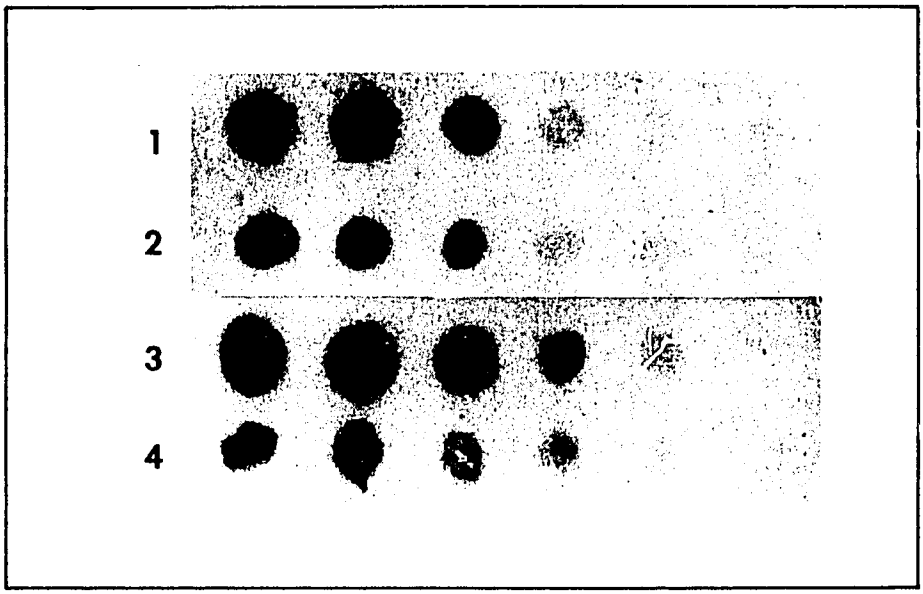

Figure 6. Detection of PSTV in true potato seed by nucleic acid spot hybridization. First and third rows, extract from PSTV-infected tomato leaves, undiluted and diluted 1:5, 1:25, 1:125, and 1:625 with extract from uninfected tomato leaves (left to right). Second and fourth rows, extracts of seed from PSTV-infected potato plants, undiluted and diluted 1:3, 1:9, 1:27, and 1:81 with extract of seeds from uninfected plants (left to right). The right most sample in each row is undiluted extract from uninfected tissue. Samples in the third and fourth rows were extracted with phenol and chloroform before application to the nitrocellulose membrane.

Results furthermore indicate that, at least under certain conditions, the test is also more sensitive than bioassay on tomato. This fact is most clearly evident in the case of the composite seed samples. Apparently, PSTV concentration in these samples, although sufficient to infect some of the assay plants (as shown by subsequent PAGE analysis), was not high enough to lead to recognizable symptoms in the test plants. The spot hybridization test, on the other hand, readily detected PSTV in all but one of the very same composite seed samples.

The one ambiguous result obtained with tuber sprouts can be explained if PSTV concentration in the tuber in question (clone MB 15.25 II) was sufficient to result in a weak positive reaction in the hybridization test, but too low to assure consistent transmission to the assay plants.

Table 2. Reevaluation of negative and contradictory results shown in Table 1.

Clone	Original results			New results		
	PAGE	cDNA		Bioassay[a]	cDNA[b]	PAGE[c]
BR 63.15 I	-	+		Mild	+	
BR 63.15 II	-	-	T-1:	-	-	-
			T-2:	Mild	+[d]	+
MB 6.11	+	+		Severe	+	
MB 6.42	-	+		Severe	+	
MB 6.1	-	+		Mild	+	
MB 30.2	-	+		Mild	+	+
MB 34.97 I	-	+		Mild	+	+
MB 15.25 II	-	±		-	-	
MS 117.36	-	+		Severe	+	
PSP 5.6	-	-	T-1:	Not done, tuber lost		
			T-2:	Severe	+[d]	+

[a] On Rutgers tomato seedlings.

[b] Nucleic acid hybridization with extracts from inoculated tomato assay plants.

[c] With nucleic acid preparations from inoculated tomato assay plants.

[d] Positive reaction also with extract from tuber.

T = tuber.

Table 3. Detection of PSTV in composite true seed samples from healthy and PSTV-infected potato plants.

Seed ratio Infected:Healthy	Symptoms on tomatoes	PAGE of tomatoes	cDNA of potato seed
0 : 16	-	-	-
1 : 15	-	-	+
2 : 14	-	-	-
4 : 12	-	+	+
8 : 8	-	+	+
16 : 0	-	+	+

One note of caution is indicated. Our results demonstrate that it may not be sufficient to test sprouts from only one tuber of a clone. With two clones (BR 63.15 II and PSP 5.6), one tuber tested negative in the hybridization test (in seeming confirmation of earlier results obtained by PAGE), but when sprouts from a second tuber of each clone were analyzed, positive reactions were obtained. We conclude that PSTV may be unevenly distributed in plants, giving rise to both PSTV-free and PSTV-infected tubers or tuber portions. Conceivably, such plants have become infected recently, and the viroid has neither accumulated to any large extent nor spread evenly through-out the plant. At this stage, PAGE analysis might not detect PSTV, but, because of its higher sensitivity, spot hybridization might.

Although the spot hybridization test takes 4 days for completion, no manipulations are required during much of this time. Thus, many samples may be applied to one membrane and be processed simultaneously and multiple membranes may be run sequentially at brief intervals. Also, automation of sample preparation (Gugerli, 1979) may further reduce the amount of labor required. The nucleic acid spot hybridization test thus is suitable for the reliable assay of large numbers of samples for the presence of PSTV.

Impact on agriculture

Practical consequences of PSTV infection

The potato spindle tuber disease poses a potentially serious threat in seed potato production, germ plasm collections, and potato breeding programs (reviewed by Diener, 1979). PSTV is transmitted through vegetative propagation, foliar contact, and true seed and pollen.

A number of independently isolated PSTV strains have been described and can be classified as either severe or mild strains on the basis of the symptoms produced in Rutgers tomato. Tomato has been used as a diagnostic host for PSTV because symptoms in some potato cultivars are indistinct. Severe strains cause extreme shortening of the internodes, severe epinasty, shortening of petioles and midribs, and necrosis of stems, petioles and midribs in tomatoes. Symptoms of mild strains, on the other hand, are slow to develop and often so mild that they are easily overlooked (Fernow, 1967).

Depending on the potato cultivar, the strain of PSTV present, and environmental conditions, symptoms of PSTV infection in potato may vary considerably. Foliage

symptoms are often obscure, and severity of the characteristic tuber symptoms depends upon temperature and length of infection. While the disease causes neither total crop destruction nor storage losses, it can cause a serious reduction in total production. As long as control is effective in keeping the incidence of disease low, yield losses are of little consequence in temperate growing areas (1-2%). Inadequate control, however, can lead to catastrophic losses (~20% for mild strains or ~60% for severe strains) in a relatively short time (reviewed by Diener, 1979).

In plants grown at high temperatures, PSTV may cause severe damage and total crop loss may ensue. Major efforts are underway to supplement the world's food supply by adapting the potato to growth in subtropical and tropical climates, and a lowland tropical potato cultivar has already been developed (Sawyer, 1978). Under these environmental conditions, PSTV poses a potentially serious threat and the importance of a sensitive, rapid, and reliable method for PSTV diagnosis is readily apparent. This is true regardless of whether potatoes are propagated vegetatively or by true seed.

Because, at present, potatoes are vegetatively propagated, virus diseases are a major problem in potato production, and practical means for the exclusion of viruses from "seed" potatoes are a necessity. A sensitive automated method for the simultaneous detection in potato tubers of several important viruses has been developed (Gugerli, 1979). This method is based on an enzyme-linked immunosorbent assay; it permits sampling of 300 tubers per hour. With the availability of the nucleic acid spot hybridization test, "seed" potato tubers can now be tested simultaneously for the presence of important viruses and for PSTV. Thus, the danger of introducing PSTV into commercial potato fields should become drasticallly reduced.

Application to other viroid diseases

Diagnostic tests paralleling the one developed for the detection of PSTV evidently may be initiated for the diagnosis of economically important diseases caused by other viroids. Because of the considerable sequence homologies of certain viroids with PSTV (Visvader et al., 1982), it may be possible to use the PSTV probe also for their detection. This particularly applies to detection of chrysanthemum stunt and citrus exocortis viroids, but the development of specific probes would be expected to result in more reliable results.

Diagnostic tests are most urgently needed with vegetatively propagated crops that are susceptible to viroid-induced diseases, such as chrysanthemum (stunt and chlorotic mottle viroids), hops (stunt viroid), citrus (exocortis viroid), and avocado (sunblotch viroid). In each case, development of a nucleic acid spot hybridization test requires isolation and purification of the respective viroid, preparation of specific cDNA, and cloning of the cDNA. Also, use of crude extracts from the various hosts as viroid source may require modification of the extraction buffer, because these host plants, in contrast to tomato and potato, may contain substances that interfere with the hybridization reaction.

Development of specific spot hybridization tests for these viroid diseases is advantageous, because such tests would replace presently used, but far less satisfactory diagnostic procedures based on bioassay in suitable indicator plants or analysis by PAGE. As with PSTV, bioassay often is exceedingly slow and requires extensive greenhouse space, whereas PAGE analysis is prohibitively expensive for most applications.

Nucleic acid spot hybridization tests may also become useful for the early detection of viroid infection in young seedlings. One case in point is the coconut cadang-cadang disease. Because of the great sensitivity of the hybridization test, it is possible that routine testing of seedlings in new plantations could identify infected palm trees long before symptoms appear or before the cadang-cadang viroid would become detectable by PAGE analysis. Early roguing of infected plam trees might materially diminish tree-to-tree spread of the viroid in these plantations. Similar considerations may apply to avocado plantations and their protection from the avocado sunblotch viroid.

Other potential applications

Nucleic acid spot hybridization tests may prove useful for the diagnosis of infection by certain conventional viruses. Thus, immunological assays may not be practical with viruses that produce labile virions or whose coat proteins are only weakly antigenic. In such cases, tests based on hybridization of the viral genome with specific cloned recombinant DNA may be more advantageous than conventional tests, although preparation of the tissue extracts probably would be more cumbersome than with viroids. Presumably, the viral genome, to be reactive in the test, would have to be liberated from virions which would require some sort of nucleic acid isolation procedure. Conceivably, however, nonencapsidated viral nucleic acid, such as RF or RI, might be present in sufficient quantity to react with the cDNA probe.

Nucleic acid spot hybridization tests are excellently suited for the identification of cryptic virus infections and of integrated viral genomes. Indeed, a conceptually similar nucleic acid spot hybridization procedure has already been described to screen eukaryotic cell lines for their Epstein-Barr virus DNA content (Brandsma and Miller, 1980).

Another possible application for nucleic acid spot hybridization tests involves the rapid screening of cell lines for the presence of genes to be inserted into the cells' genome by recombinant DNA procedures. Undoubtedly, nucleic acid spot hybridization tests have many applications in addition to those listed here.

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BREEDING OF POTATOES FOR GREATER PHOTOSYNTHETIC EFFICIENCY AND GREATER NITROGEN EFFICIENCY

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Many agricultural analysts lament the fact that we have reached apparent yield plateaus with many crops, including potatoes. To break these plateaus, we need greater involvement by physiologists within the breeding programs. At present, most breeders select for high yield empirically by viewing the end product of plant production. However, final marketable yields are obviously the result of many physiological processes interacting with environmental conditions. If we can identify potato clones that are particularly efficient in given physiological processes, we can cross these clones in an effort to combine these characteristics. We have begun this approach in Idaho.

We have identified several potato clones that have higher rates of photosynthesis (Dwelle et al., 1978, 1979, 1980, 1981a, b, c). In addition, the upper (adaxial) leaf surface of some potato clones provides a surprising contribution to total carbon assimilation (Dwelle et al., 1981c). For example, the Lemhi variety

has an unusually high rate of CO_2 assimilation through the upper leaf surface, and clone A6948-4 an unusually high rate through the lower leaf surface. This raises the intriguing question: through breeding can we combine the high carbon assimilation rates of Lemhi's upper leaf surface and A6948-4's lower leaf surface? Preliminary measurements using 182 progeny from this cross suggest it may be possible.

We have also identified a potato clone that is very efficient in the uptake and utilization of soil nitrogen (Kleinkopf et al., 1981). For example, at low soil nitrogen levels (170 kg/ha available N) clone A66107-51 utilized 99% of available nitrogen compared with 68% for Russet Burbank, 75% for Lemhi Russet, 79% for Norgold Russet, and 71% for Pioneer. Clone A66107-51 also out-yielded the others (43.3 t/ha vs. 25.8 t/ha for Russet Burbank). At high soil nitrogen levels (570 kg/ha available N) clone A66107-51 continued to be more efficient utilizing 71% of available soil N compared with 40 to 52% for the other varieties. Yield by A66107-51 was again higher (62.5 t/ha vs. 43.1 t/ha for Russet Burbank). Clone A66107-51 is also more efficient than Russet Burbank in carbon assimilation (Dwelle et al., 1981a).

We have crossed this nitrogen-efficient clone (A66107-51) with the carbon-efficient clone (A6948-4). Eighty-four progeny from this cross were examined in '81 in the 12-hill stage, and 64 of these will be examined in greater detail in '82 under both normal and low nitrogen levels. Naturally we are looking for progeny that will maintain high rates of photosynthesis under low nitrogen levels.

As discussed previously (Dwelle et al., 1981b), critics of photosynthesis research have pointed to the low correlations between short-term measurements of photosynthesis and economic crop yields. Such lack of correlation is not surprising since many physiological functions contribute to and often limit yields. Nevertheless, higher rates of photosynthesis are an essential step toward developing substantially higher yields. Plant breeders must accumulate parental lines with high photosynthetic rates as well as with efficient nutrient uptake, increased disease resistance, etc., and then breed to combine these attributes. If we do not have high photosynthetic potential, it is doubtful we can develop substantially higher yields regardless of the other virtues present.

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STRATEGY FOR CONTROLLING POTATO TRUE SEEDLING DAMPING-OFF CAUSED BY RHIZOCTONIA SOLANI IN THE PERUVIAN LOWLAND TROPICS

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Introduction

Post-emergence seedling damping-off is a disease complex caused by a combination of biological and environmental factors including Rhizoctonia solani and high soil temperatures respectively. It is a major limiting factor to potato production from true seed (Table 1).

Table 1. Disease problems of potato production from potato true seed.

Disease and causal agent	Main symptoms and (loss %)	Control
Pre-emergence damping-off (seed bed) Rhizoctonia spp. Pythium spp.	Germination failure (0 - 80%)	Fungicidal seed or soil treatment Steam sterilized soil + 0.2% fungicidal drenching Use of subsoils
Post emergence damping-off complex (field) Rhizoctonia spp. Pythium spp. Cutworms High soil (temperatures 30°C)	Wilting and death of transplants within 20 days (0 - 35%)	Plant vigorous seedlings Timed fungicidal/ insecticidal application within first 20 days Mulching, shading, intercropping Nitrogen application.

Under favorable conditions, field losses approach 40% within 15 days after transplanting. Rhizoctonia-infected transplants show characteristic stem lesions. Epidermis and cortex damage results from mild infection while in severe infections the vascular system is destroyed causing the transplant to wilt and fall over at the soil line. Effective control measures must take into consideration many environmental and management factors (Table 2). This paper examines some variables that could be easily manipulated to reduce damping-off losses in the lowland tropics-characterized by high air and soil temperatures and infertile soils.

Table 2. Variables important in developing strategy for controlling post emergence damping-off of true potato seedlings caused by Rhizoctonia solani.

Variables		
Environmental	Seedling characteristics	Management practices
Soil and air temperature Location: Huancayo, Lima, San Ramon, Yurimaguas Transplanting date & season Soil inoculum level	Genetic influence size vigor resistance and/or tolerance Age	Transplanting Method: jiffy ball of earth Number of transplants per hill Irrigation, Mulching, Shading, Intercropping Previous crop history Insecticides, Fungicides, Fertilizers, (type, rate, timing and sequence of application)

Transplanting method

Previous agronomic trials (Accatino, 1979) have demonstrated that 3-5 seedlings per stand enhanced transplant survival. Field trials have also demonstrated that higher transplant losses occur with the ball of earth method than with the jiffy method because in the former, roots are disturbed or damaged, as well as coming in early contact with soil inoculum. However, because jiffies are expensive and not locally available, the ball of earth transplanting method or an adaptation of it offers the most attraction to growers in the tropics. Already, an adaptation of the latter involving sowing seed directly in square blocks of soil mix and later transplanting is in use at CIP (Malagamba 1981; unpublished data). This method obviously encourages early plant establishment and, by extension, possibly reduces plant stress which predisposes transplants to pest and disease problems. The use of small tubers from nursery bed seedlings (Wiersema-Unpublished data) may also offer a potential for damping-off control in that unlike transplants, new tuber sprouts are formed once one is destroyed. Ultimately, the choice of a transplanting method depends on the cost/benefit analysis of each technique and the prevailing circumstances of the grower.

Air and soil temperature

Plant stress or damage due to environmental factors such as temperature often predisposes seedlings to disease such as Rhizoctonia solani induced damping-off. Exposure of potato seedlings to high air temperatures of up to 40°C (CIP, 1979) indicated that some transplants can adapt and tolerate these temperatures. However, transplants subjected to average soil temperatures of over 30°C at the 0-10 cm depth appeared to be injured. Plant wilting and significant weight losses resulted, compared with seedlings growing at 25°C temperatures. Soil temperatures of 30°C easily predispose seedlings to Rhizoctonia solani in the greenhouse to the extent that higher damping-off losses result, and symptoms appear about 10-15 days earlier than for seedlings growing at 25°C. Differences were also observed in the susceptibility of seedling clones and varieties to Rhizoctonia solani over a 21-day period at 20°C, whereas most clones, including tropically adapted ones, were completely susceptible to heat-preferring Rhizoctonia isolates within a week at 35°C soil temperatures. The mechanism of plant tissue injury or death by high temperatures includes inactivation or acceleration of certain enzyme systems, protein denaturation, cytoplasmic membrane disruption and possibly, release of toxic products into cells. However, the end effect of such injurious temperatures on plant cells depends on its duration.

Consequently, our management practices must aim at lowering soil temperatures to below 30°C, especially during mid-day hours. Any such measures would reduce wilting losses and seedling predisposition to damping-off. Moreover at lower soil temperatures many fungicides are apparently more effective, stable, and persistent.

Mulching, shading, and intercropping

The objective of mulching and shading is to reduce plant stress due to soil and air temperatures and to improve the microclimate of the transplant. Grass mulch reduces soil temperatures during the day by about 5°C (Midmore: personal communication) and this reduction could make a difference between heavy or faster damping-off losses and low or slower losses. Currently, the use of temporary transplant shades such as corn in popular. Some fast growing tropical shade trees could be useful in the future. Intercropping transplant with peanuts, sweet potatoes or soybeans (Raymundo 1981: unpublished data) indicated that damping-off could be significantly reduced. The mechanism of this phenomenon possibly involves the release of inhibitors by plant root exudates which in turn may support microflora antagonistic to Rhizoctonia solani.

Chemical control

The use of insecticides and fungicides is necessary in control of damping-off. However, types of fungicides, doses and their timing have to be determined in order to avoid unnecessary applications as well as losses due to phytotoxicity. Studies to determine the effectivity, persistence and stability of insecticides and fungicides in hot tropical soils would improve damping-off control. Pathogen tolerance to fungicides is common knowledge; therefore, trials of fungicidal combinations and sequences of applications are being conducted.

Mycorrhization and bacterization

In soil deficient in nutrients, especially phosphorus, mycorrhization with vesicular-arbuscular-mycorrhiza may offer a potential for the slow growing and poor root system of potato transplants. Significant growth responses could be stimulated in infected seedlings, thereby providing a possible escape mechanism against damping-off organisms. Other attributes of mycorrhizae include enhanced water transport in plants, decreased transplant injury, helping transplants withstand high temperatures and reducing the effect of root-infecting fungi. One possible mode of action of endomycorrhizae on root pathogens and disease includes increased cortical cell wall thickenings of mycorrhizal roots which deter penetration by the pathogen (Schenck, 1981). Methods for pre-inoculation of seedlings in trays or beds before field transplanting offers intriguing prospects. By the same token, pelleted true seed infected with mycorrhiza for direct field seedling may offer possibilities.
Similarly, the use of any potential plant growth-promoting rhizosphere bacteria isolated from tropical potatoes could also help seedling establishment and disease control. These bacteria, when present, generally stimulate growth by displacing harmful microorganisms that commonly colonize roots. If successful, both mycorrhization and bacterization could reduce costly fertilizer application in tropical potato farming.

Conclusion and future trends

By the year 2,000 the production of potato from true seed would likely be increasingly commercialized and mechanized. The control strategy for post-emergence damping-off would invariably be integrated involving the use of vigorous-growing tropically adapted seedlings, appropriate insecticides and fungicides with stability and persistance under high soil temperature regimes as well as the use of management practices such as mulching, shading and nitrogen application. Under certain farming systems, intercropping, crop rotation and programming of transplanting dates within a growing season to avoid heavy pest and pathogen populations could be applicable. The beneficial interaction effect of field scale mycorrhization and bacterization of transplants on Rhizoctonia control could become a future phenomenon.

Finally, control strategy will vary with location, farming systems and the grower's circumstances.

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TESTING CIP AND ICA POTATO SELECTIONS FOR LATE BLIGHT RESISTANCE AND YIELD AT RIONEGRO (LA SELVA) STATION IN COLOMBIA

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(Joint cooperative project of ICA and CIP).

Summary

Some of the climatic and other factors are described that make the ICA-station at Rionegro, Colombia, an excellent site for late blight evaluation and breeding of potatoes destined for mid elevation tropics. Two seasons a year provide opportunity to advance rapidly with an evaluation and selection programme. Results of 2 years of evaluation of CIP, ICA and Mexican clones obtained in late blight breeding programmes are summarized.

Introduction

Late blight is probably the most severe potato disease, and a prime production constraint all over the world. Chemical control is expensive requiring frequent spraying of fungicides. Breeding for resistance to this disease is and has been of primary importance to CIP's program. A site to evaluate late blight resistance is however not available at any of CIP's experiment stations in Peru. There are only few places in developing countries where a combination of laboratory facilities, institutional personnel organization as well as a constant presence of late blight can be found.

The ICA (Instituto Colombiano Agropecuario) station "La Selva" in Rionegro near Medellín (6°20'N, 75°20'W at 2,200 m above sea level) fulfills such basic requirements. In addition it allows to plant and evaluate during 2 seasons in each year, due to the occurrence of 2 rainy seasons. Temperatures vary little throughout the year and from year to year: daily minima are from 10 to 12°C, daily maxima are from 22 to 25°C, with daily averages of 16 to 18°C.

The combination of these environmental conditions make the location very favorable for epidemics of late blight and consequently very desirable as a site for testing genetic material. In addition these climatic factors, together with the well drained volcanic soil are almost ideal for the growing of different potato species such as Solanum tuberosum, S. andigena, S. phureja and their hybrids. These 3 species are of prime importance in potato breeding for blight resistance.

The Rionegro station is also ideally situated to test for general adaptability of germplasm, as the most important potato diseases of the tropical highlands are rather serious: PVX, PVY, PLRV, bacterial wilt (Pseudomonas solanacearum, early blight (Alternaria solani) and Phoma leafspot (Phoma sp.) all cause serious losses in susceptible varieties.

The concept of general resistance to late blight was introduced by 1956. This resistance is supposed to have a high degree of stability over time and possibly space.

However, with few exceptions this type of resistance has not been incorporated into potato cultivars. High levels of this resistance are found in accessions of S. andigena and S. phureja and in some wild species. It is expected that use of these species in a breeding program will rapidly lead to the obtaining of desirable cultivars with general resistance to blight and suitable for the needs of the mid elevation tropics.

Materials and methods

Tests were performed since 1979 using tuber families and clonal materials sent in from CIP Lima and ICA, Bogotá. They included selected clones and materials from tuber families produced specifically for late blight resistance. Susceptible checks, local varieties and R-gene differentials (obtained through courtesy of L. Turkensteen, IPO, Wageningen) were also included. Clones to be tested were planted in CRD with 1 to 4 replicates in March-April and in August-September of 1979, 1980 and 1981. Herbicides and insecticides were applied but protective fungicides were excluded except during the first 45 days after the planting. As soon as symptoms appeared in susceptible clones, sometimes as early as one month after emergence, notes were taken at intervals of 7 to 10 days on Phytophthora infection. The scale used was the 1 to 9 scale developed at CIP (Table 1) in which grade 1 represents no visible disease and 9 no healthy foliage left. Normally, 4-6 readings were made. Notes on other diseases were also taken.

Harvest data included tuber size, shape, eyes, skin, flesh color, and yield. The most resistant, highest yielding and agronomically most attractive clones were selected. The clones selected were retested in succeeding seasons.

The genetic background of the clones tested included: S. andigena from Peru, Colombia, Ecuador and Bolivia, S. tuberosum selected in cooperative tests with INIA at Toluca in Mexico. Many of these latter selections originated in The Netherlands, Scotland, Germany, India, USA, Sweden and Mexico. These contained in addition to S. tuberosum and S. andigena, also S. phureja, S. demissum, S. stoloniferum and other wild species among progenitors. The tuber families from CIP were derived from S. tuberosum and its hybrids with the mentioned species which were highly resistant in Mexico and crossed to andigena clones from Andean countries specially selected for their yield, quality and some degree of Phytophthora field resistance.

Table 1. Scale used for estimating late blight field resistance.

Grade	Foliage affected %	Description of damage
1	0	very few or no lesions
2	3	over 0% but less than 10% damage
3	10	
4	25	
5	50	half of the foliage damaged
6	75	
7	90	
8	97	very few disease free portions; less than 10% of total area
9	100	complete foliage destruction

Results and discussion

A total of 79 tuber families, which included 5,149 potential clones were tested in 1980 and 1981, from which 336 were selected for future tests. The average yield of six local check-varieties was 0.4 kg/plant as compared to 1.5 kg/plant of 102 selected clones.

At the same time clones obtained in Mexico and selected by CIP for late blight resistance, as well as clones selected through ICA's program gave yield averages and late blight infection scores as shown (Table 2). Twenty clones from the CIP breeding program selected and retested in Rionegro in replicated trials, yielded between 1 and 1.8 kg per plant and showed a final infection level of 2 to 5 (results not shown). All R-gene differentials appeared very susceptible (Table 3), indicating that racial variability was for practical purposes as wide as in Mexico or Costa Rica, in tests in former years. A summary of the results for the three types of clonal material tested is given in Table 4).

Table 2. Tuber family trials at La Selva in 1980 and 1981.

	1980-a	1980-b	1981-a	Total
Tuber families tested	27	27	25	79
Clones tested	2,142	1,168	1,839	5,149
Families selected	26	20	21	67
Clones selected	124	94	118	336
Clones yielding over 1.0 kg/plant	86	75	77	238
Clones yielding over 1.5 kg/plant	37	35	40	102
Average yield of local checks (kg/plant)	0.6	0.3	0.4	0.4
Rainfall during growing season (mm)	560	780	950	

a = March-April planting.
b = August-September planting.

Table 3. Late blight readings made two months after planting, on late blight differentials at La Selva Station, 1980.

Differential	Blight reading
r	9
R1	5
R2	7
R3	8
R4	6
R5	6
R7	5
R10	4
R2 R3	6
R2 R4	6
R1 R2 R3	9

R6, R8 and R9 differentials were not available in the test.

Table 4. Average yield and late blight readings of diverse clonal groups tested at La Selva Station with no fungicide.

Material	Origin	Foliage damage (scale 1 to 9)	Yield (kg/plant)
ICA selected clones and Colombian varieties	tuberosum, andigena	7.0	0.4
CIP selected clones from Mexico, Perú, USA, Germany, Netherlands, Scotland, India	tuberosum, demissum phureja, stoloniferum	4.5	0.7
ICA-CIP testing and selection project from tuber families	combination of 1) and 2)	3.5	1.2

It is concluded from the results obtained so far, that:

The ICA Station at Rionegro is excellent for the evaluation of materials with general resistance to late blight.

Several CIP selections from mexican material show also in this location a satisfactory degree of late blight resistance and a relatively high yield.

Selected clones from CIP's breeding program and with quite diverse origin, including S. tuberosum, S. demissum, S. andigena, S. phureja, and some wild species were outstanding in their performance for high yield, quality and general late blight resistance.

The best clones are increased and rogued at an ICA Station at 3,000 m of altitude, to produce seed for growers trials in the coming years.

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IN VITRO STORAGE OF POTATO GERMPLASM

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Abstract

Established cultivars from different countries, as well as advanced potato germplasm developed by the breeding program at the International Potato Center are freed of pathogens by meristem tip culture, propagated for distribution to developing countries and maintained in vitro for future research.

Investigations are carried out to find conditions which allow increasing the periods between transfers of in vitro plants to fresh medium without interfering with vitality or genetic stability. Results obtained with a wide range of genotypes are presented.

Introduction

The collection of pathogen tested potato clones at CIP contains about 170 clones of different origins and ploidy levels. It includes cultivars and advanced breeding lines, and each year more clones are added. This collection is utilized for evaluation and breeding in many regions of the world because of its excellent health status which permits easy distribution to other countries (Roca et al., 1978).

Under normal growth conditions (Roca et al., 1978) in vitro storage is labor intensive, since nodes of plants have to be transferred to fresh medium and regenerated into plants every 2 to 3 months. Different conditions have been described which reduce the frequency of transfer and regeneration (Westcott et al., 1977; Schilde, 1979; Westcott, 1981b; Radatz and Standke, 1978; Mix, 1981). Storage especially at cycling low temperature, gives high survival rates only for some genotypes (Westcott, 1981a). Therefore, these storage conditions are not suitable for germplasm banks that have a large range of genotypes. In addition, the necessary facilities may not be available in developing countries.

At CIP the collection of pathogen-tested clones has been stored in vitro without transfer for one year at 25°C on a medium containing 4% mannitol and 0.5% sucrose (Table 1, M4). In this study, the effect of sucrose concentrations and mannitol in the culture medium on reduction of growth without interfering with plant vigor was evaluated to further improve in vitro storage.

Materials and methods

The culture media used for propagation and maintenance of potato clones are presented in Table 1. The pH of all media was adjusted to 5.6 before autoclaving. In vitro plantlets of four potato clones were used: LT-1 (tbr), Maria Tropical (adg), DTO-2 and MS-1C-2 (phu x tbr). These clones were derived from meristem culture, maintained on medium 1 and propagated in shake culture (60 rpm, 25°C, 100 fc 16 h/day) in medium 9 to obtain sufficient homogenous material (Table 1). Shoot apices from these plantlets were incubated at 22-25° at 300 fc for 16 h/day on agar media A - E (Table 2) in tubes.

Table 1. Culture media for propagation and conservation of germplasm in vitro.

Additions	Media for 1/		
	1	M4	9
Sucrose (g/l)	30	5	20
Mannitol (g/l)	-	40	-
Ca Pa (mg/l)	2	-	2
GA (mg/l)	0.25	-	0.4
BAP (mg/l)	-	-	0.5
NAA (mg/l)	-	-	0.01
Agar (g/l)	8	10	-

1/ 1 - normal growth, M4 - long-term storage, 9 - rapid propagation; using basic medium of Murashige and Skoog (1962).

GA - gibberellic acid
CA Pa - D-pnthothenic acid hemicalcium salt
BAP - 6-Benzyl-amino-purine
NAA - α-naphthalene acetic acid

Table 2. Shoot lenght (mm) of plantlets grown on media for 4 months.

Medium 1/		Clone			
	S M	LT-1	DTO-2	MS-1C-2	M.Trop.
A	0-40	8.17	6.67	11.83	11.18
B	5- 0	44.33	25.50	20.50	15.67
C	5-40	27.50	7.83	18.33	11.50
D	30- 0	79.17	90.67	81.33	56.18
E	30-40	38.33	15.00	23.33	14.33

1/ Basic medium of Murashige and Skoog (1962) containing 1% agar with addition of sucrose (S) and/or mannitol (M) in g/l.

Results and discussion

Growth responses on the media A to E measured as total length of the plantlets after 1.5 and 4 months are shown (Table 2, Figure 1). Survival rate at evaluation time was almost 100% for all 4 clones, except for losses by contamination.

Comparison of different concentrations of sugar (sucrose and/or mannitol) (media A, B and D or A, C and E, Figure 1) shows that 3% sucrose is adequate for normal growth (Media D and E). Low concentration of sucrose (B) caused strong reduction in growth rate, and parts of shoots died. The plantlets with mannitol but without sucrose (A) were more vigorous than the former. Whether mannitol is metabolized by plants is not known.

In media containing mannitol (A,C,E) the growth was reduced, but the reduction was less pronounced when the sucrose concentration was high (E). At high sucrose concentrations plantlets were more vigorous (D and E). Incubation for longer periods will be necessary to be able to ascertain if medium F (4% mannitol, 3% sucrose) is as good or better than medium C (4% mannitol, 0.5% sucrose) which is routinely used presently (M4-Table 1).

A relationship exists between root formation and sucrose concentration. At higher concentrations, the number and length of roots are higher.

In the presence of mannitol the number of nodes per cm increases and the length of the internodes is reduced. Whether the effect of mannitol on growth rate and morphology is due only to its capacity to induce osmotic stress (Thorpe, 1978; Laisne and Codaccioni, 1978) is not known.

To determine that osmotic stress induced by mannitol in the culture medium has no influence on the genetic stability of the clones, tuber extracts from plants derived from in vitro stored material were compared in polyacrylamide gel electrophoresis to conventionally propagated plants (Stegemann and Loeschke, 1976). No differences in the band pattern have been observed.

The mannitol containing medium reduces the need for transfer at 25°C to a maximum of once a year. At lower temperatures, the need for transfer may be less (Schilde, 1979; Westcott, 1981a). More progress in long-term in vitro storage will be possible if techniques for cryopreservation are efficient enough to obtain high survival rates of whole meristems not only for a few (Grout and Henshaw, 1978; Withers, 1980), but for a wide range of genotypes.

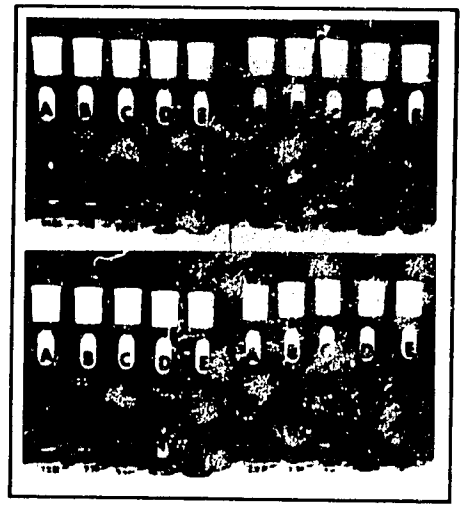

Figure 1. Comparison of four clones grown on medium A, B, C, D and E (Table 2) for seven months at 25°C.

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SELECTING FOR HEAT TOLERANCE WITHIN POPULATIONS DERIVED FROM THE CORNELL ANDIGENA COLLECTION

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The goal of our heat tolerance program is to develop a population, derived from the Cornell andigena collection, that will combine heat tolerance and early maturity with resistance to PVY, late blight, bacterial wilt, and root-knot nematodes. To accomplish this we must have an effective screening technique to select for heat tolerance and early maturity.

The approach that we have adopted is to grow populations in a plastic greenhouse that is allowed to reach a maximum day temperature of 40°C and a minimum night temperature of 30°C. Timers and artificial lights maintain an 18 hr photoperiod. Plants, either from true potato seed or from tubers, are allowed to grow at least 2-3 weeks under these conditions. When the plants have developed eight or more leaves longer than 3.5 cm, one apical cutting and two leaf-bud cuttings are taken from each plant and placed in a mist bench under continuous light. Ability to form a tuber on one or more of the cuttings is considered to be an indication of early maturity and possible heat tolerance (Ewing, 1981).

It may seem odd that we choose to maintain 18 hr photoperiods in a heat screening test for the tropics. We have found that at high temperatures the difference between tuberization of cuttings from heat tolerant clones and heat sensitive clones is fully as great under long photoperiods as under short ones (Ewing, 1981, Figure 5). At the long photoperiods it is easier to separate the responses visually, because tuberization of the sensitive cuttings is virtually eliminated, giving a "plus or minus" response.

Testing in greenhouses and growth chambers indicated that clones selected by the cutting technique possessed heat tolerance under artificial conditions. Field testing was therefore carried out for heat tolerance at CIP plots in San Ramon, Peru. Experiments carried out during the summers of 1977-78 and 1978-79 showed that some of the selected clones gave reasonable yields in 11 weeks and that earlier maturing clones resulted from the screening technique. Larger experiments were needed to determine whether the technique led to higher tuber yields. Part of the difficulty in evaluating the screening technique at San Ramon is the high incidence of a soft rot disease. This disease, believed to be caused by Erwinia chrysanthemi, leads to poor emergence, weakened plants, and rotting tubers. The cutting technique used in the greenhouse screening does not include conscious selection against susceptibility to this disease.

During the 1980-81 season, field testing was carried out on 72 clones selected as heat tolerant by the cutting technique. The clones were selected in the hot greenhouse during the summer of 1979, multiplied in the greenhouse during the winter of 1979-80, and shipped to CIP headquarters for planting in 5-hill plots at San Ramon and Yurimaguas. An additional 18 clones from the same crosses, unselected with respect to heat tolerance, were planted at random among the 72 selected clones at each location. Four 5-hill plots of the heat tolerant clones DTO-28 and LT-1 were randomized among the 90 plots at each location to serve as standards for comparison. Plantings at San Ramon were made on December 17, 1980, and plots were harvested 77 days later. The Yurimaguas plots were planted January 5 and harvested after only 64 days.

Many of the plants at Yurimaguas were badly infected with bacterial wilt, and the severity seemed to vary greatly from one part of the experiment to another. Yields of the two standard cultivars showed extreme variation from one replication to the next. Thus the results were of limited value.

There may have been a small amount of bacterial wilt at San Ramon also, but the principal problem there again appeared to be the bacterial soft rot disease. Before harvest seriously weakened plants in each plot were identified, and only tubers from the strong plants were harvested. Yields were computed as tuber weight per strong plant, but only if there were at least four strong plants per plot. Sixty of the 72 selected clones, 14 of the 18 unselected clones, three of the four LT-1 plots, and all four DTO-28 plots met this criterion. DTO-28 and LT-1 produced 0.58 and 0.45 kg per plant, respectively. Selected clones gave 0.39 kg compared to 0.35 kg per plant for the unselected. Eleven of the selected clones surpassed both standard cultivars in total tuber yields, and 15 surpassed both in yield of well-shaped tubers. None of the unselected clones were better than the standards. Selected clones tended to be earlier in maturity than the unselected clones or the standards.

Observations at San Ramon suggested that although the screening method based on cuttings was helpful, it might be improved by adding other selection criteria. For example, 10% of the selected clones were rated as having large leaves, large haulms, and thick stems at San Ramon. These had more than 50% higher yields than the overall average for selected clones. The ratings for stem, leaf, and haulm size were significantly correlated statistically with yields. We therefore tried to improve the selection process by growing the clones again and looking for characteristics that might be correlated with performance at San Ramon. Seed tubers were available for 58 selected clones and 11 unselected clones that had been grown at San Ramon. These were planted in the Cornell hot greenhouse (described previously) and in a cool greenhouse that had ambient temperatures and 18 hr photoperiods. Also planted in both greenhouses were nine tuberosum cultivars.

There were significant correlations between yield at San Ramon and yield in the hot greenhouse. Vigor ratings, leaf size, and tuberization on cuttings in the hot greenhouse were also significantly correlated with yield at San Ramon. None of the variables examined in the cool greenhouse were significantly correlated with yields at San Ramon. Of the variables in the hot greenhouse, vigor ratings and tuberization on cuttings were most effective in accounting for the variation in San Ramon yields. According to regression analysis, these two factors were associated with 24% of the variation. Tabulation of yields from San Ramon by their vigor ratings in the hot greenhouse as well as by their percent tuberization on cuttings demonstrated the improvement in yield prediction by considering both factors. The ten clones that had tuberization on at least 25% of cuttings taken from the hot greenhouse and that were rated highly vigorous in the hot greenhouse had produced an average yield of 0.50 kg per plant at San Ramon, compared to 0.45 kg for LT-1. The ten clones that had less than 25% of cuttings tuberized and that were not rated highly vigorous in the hot greenhouse had produced only 0.30 kg per plant at San Ramon.

It was interesting that several of the unselected clones produced better yields in the hot greenhouse than did most of the tuberosum cultivars. This may be explained in part by the fact that the maternal parents employed in the crosses were previously identified as possessing heat tolerance. (We have found that the maternal parent contributes more to heat tolerance and early maturity than does the pollen parent.) In the cool greenhouse the unselected clones and the tuberosum cultivars averaged higher yields than did the selected clones. This shows that the heat tolerance is not simply a function of overall yielding ability.

Twenty-six of the selected clones were also grown in the field at the Cornell University vegetable research farm. Growth measurements were again compared to yields of these clones previously recorded at San Ramon. Several characters, especially leaf size and stem diameter, seemed to be correlated with tuber yields at San Ramon, but this requires confirmation with a larger and more diverse population of clones.

We conclude from these experiments that: 1) The value of selection for heat tolerance based upon tuberization of cuttings from the hot greenhouse was confirmed. 2) The selection may be improved by also taking into account the vigor of plant growth or leaf size in the hot greenhouse. 3) It is possible that further selection based upon plant type in the field under cool temperature conditions may prove useful, but this requires further investigation. 4) Field testing for heat tolerance at Yurimaguas should become more meaningful when resistance to bacterial wilt has been incorporated into the breeding population.

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PROSPECTS FOR STABILITY OF RESISTANCE TO POTATO VIRUS Y

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Potato virus Y (PVY) is one of the two most important viruses affecting the potato crop on a world-wide basis.

In developing countries where seed certification programs are not well developed, there is a very strong need for cultivars with resistance to this virus. At CIP, breeding for resistance to PVY has been assigned a high priority and improved material with resistance to this virus alone or in combination with resistance to PVX and other pathogens is being developed.

In different crops including potato high levels of resistance to viruses are conferred by genes for hypersensitivity.

In few cases such as in the bean common mosaic virus - bean, and specially in the tobacco mosaic virus - tobacco pathosystems, genes for a high level of hypersensitivity, have conferred stable resistance to a wide range of strains.

However in many cases as in potato pathosystems it is strain -specific, leading to unstable resistance.

This unstable resistance is shown in the case of the PVX-potato pathosystem, for the genes Nx or Nb for hypersensitivity, compatible strains arise that overcome this resistance.

The PVY- potato pathosystem is one of the two cases, among virus diseases, (the other one being the PVX- potato pathosystem) in which gene for 'immunity' has been identified and transferred to commercial cultivars. 'Immunity' to PVY was first stated by Stelzner (1943) but confirmed by Ross in 1951 in S. stoloniferum (Ross, 1952). The gene Ry for 'immunity' to PVY from S. stoloniferum was incorporated by Ross to S. tuberosum-varieties (Ross, 1958). At the present time German and other european potato breeding programs have released commercial cultivars with the Ry gene. Muñoz et al., (1975) and CIP research have identified 'immunity' in S. andigena. 'Immunity' is the highest level of resistance to PVY available and the development of clones with the 'immune' level of resistance is the objective at CIP. An important consideration is the future stability of this level of resistance.

The Andean region which is the center of origin of the potato, offers the possibility for providing great natural variability in PVY. Selected potato clones, with 'immunity' to potato virus Y (PVY) derived from Solanum andigena and Solanum stoloniferum, used as parents in the breeding program for resistance to PVY at CIP, were challenged with strains prevalent in potato fields from the Andean region: Chile, Argentina, Peru and Ecuador. They belonged to the PVY^O, PVY^N and PVY^C group of strains.

After grafting the clones as stocks with PVY infected N. occidentalis scions, hypersensitive controls showed systemic necrosis, but all the selected clones remained 'immune', they did not show symptoms and were not infected as determined by two generation evaluations by ELISA serology tests and backtesting to tobacco White Burley.

The parents and the number of isolates used in challenge tests are shown (Table 1). The 'immune' reaction of the selected clones to the diversity of strains tested indicates the potential stability of resistance to PVY in the resistant material being bred at CIP. This is our hope into the next century.

Table 1. 'Immune' clones most tested against a wide range of PVY isolates from PVY^O, PVY^N and PVY^C groups of strains.

Source of immunity and clone	Isolates tested	Origin
S. andigena XY 14.7	9	International Potato Center
S. stoloniferum 78C 11.5	7	International Potato Center
S. stoloniferum PG 295	20	Mlochlow, Poland 1/
S. stoloniferum BL 61.74.167	16	Wageningen, Netherlands

1/ Derived from MPI 55.957/24

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POTATO PLANT HEALTH - SOME PROBLEMS AND PROSPECTS

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Introduction

Fox (1981; 102 references) cited papers, reviews and bibliographies providing access to most important literature on potato pathology to ca. 1900. He commented that it is easy to justify research on major diseases, but there are problem areas pertaining to plant health often ignored by potato pathologists and allied workers; the rhizosphere, rhizoplane (plus parallel tuber effects) and phylloplane, mycorrhiza and minor root infections, their interactions with diseases and nematodes, the effects of broad spectrum pesticides on microbial balances, and the mediating action of herbicides on susceptibility and symptom expression.

Subterranean Problems

Potato roots, stolons and underground stems are commonly infected by many pathogens most studied as tuber rots. Apart from the wilt pathogens, and despite the fact that the potato is acknowledged to have a barely adequate root system, very little is known about the effects on growth and yield of such infections although their increasing levels through the growing season have been related to concomitant increases of tuber infections. Thus Fox and Dashwood (1979) resolved conflicts between decreasing tuber susceptibility but increasing incidence of gangrene (Phoma exigua var. foveata) in storage with late harvesting. Table 1 (after Spencer and Fox 1979) shows a progressive relationship between black scurf (Rhizoctonia solani) on tubers, and root and stolon infection, and introduces an effect analysed by them relating tuber periderm maturity and rhizosphere (sensu tubersphere) effects. In simplest terms, sclerotia are initiated at high but are induced to mature by certain lowered nutritional levels; these are affected in time (through the season) and space (tuber surface) by periderm maturity. The potential effects of tuber exudates on the distribution and severity of black scurf (Table 2) were explained by comparing differential skin maturity from the rose to the heel end with maturity along a root from its tip backwards as they affect rhizosphere activity (Spencer and Fox, 1975, 1978).

Table 1. Incidence of R. solani on stolons and roots; periderm maturity rating (PMR), and mean black scurf severity score (BSSS) on cv. Majestic at 2-weekly intervals from 5 August.1/

	Week					
	1	3	5	7	9	11
roots	48	67	77	75	90	96
stolons	52	65	74	76	95	98
PMR	100	95	85	85	35	5
BSSS	0.6	0.6	0.9	1.0	1.5	2.1

1/ Data derived from and experimental details in Spencer and Fox (1979).

Table 2. Percent incidence and infection severity rating of R. solani on four zones of tubers of field grown cv. Majestic (n=430)[1/]

	Zone			
	1(rose)	2	3	4(heel)
Incidence	83	70	61	47
Severity	48	22	13	6

1/ As table 1

Black dot (Colletotrichum coccodes, syn. C. atramentarium) can cause a severe wilt under hot arid conditions. Davis (1981) commented that it is "illusive and lack of recognition is frequent". In Scotland, in the UK generally, and often elsewhere it is regarded as of little or no consequence, but we have recorded it as common colonizer of roots, stolons and stem bases that occurs with increasing frequency as the season progresses (Table 3). It is difficult to accept that such levels of root infection do not affect growth and yield; it may be that its commonness and uniformity has stifled enquiry and obscured its effect.

Table 3. Numbers of Petri dishes containing C. coccodes growing from pieces of surface sterilized below ground stem, stolons and roots from cv. Pentland Crown.

	Date		
	07 Sep	24 Sep	24 Oct
stems	21 (28)	28 (28)	23 (28)
roots	24 (28)	^{a}65 (70)	^{b}47 (65)
stolons	24 (28)	^{a}37 (70)	^{b}50 (70)^{c}

Numbers of root pieces yielding C. coccodes was ^{a}139 and ^{b}97, and of stolons ^{a}93 and ^{b}92 of a potential 140 at the second and third harvests respectively.
(xy)^{c} = total number of Petri dishes.

For some tuber diseases, root, stolon and stem base infection doubtless increases inoculum as the plant becomes senescent (Fox, 1981), an increase accelerated by haulm destruction, but the question posed by Fox remains: "Does senescence of the root system precede or follow that of the haulm? Is there a consistent sequel of precedence or does it vary with season site and soil type and with the extent of attack by 'tuber' and other pathogens on the roots and the varying extent to which these may be tuber-, soil-borne or both?"

Phylloplane

Fox (1981) reviewed the limited knowledge of the potato phylloplane. Perombelon (1981) did so in relation to air-borne dispersal of Erwinia carotovora ssp. carotovora and ssp. atroseptica. He has demonstrated their potential for multiplication on the leaf surface and how they may be washed thence by rain into the soil to contaminate progeny tubers. (Important additions to the literature on air-borne dispersal cited by Fox, have been provided by Kloepper, Brewer and Harrison, 1981; and Kloepper, Harrison and Brewer, 1981). The surface of the plant thus offers access for chemical control in a life cycle now known to be very complex and in which the bacteria are mostly inaccessible. Table 4 gives the results of a preliminary small-scale experiment with a copper spray applied to field grown plants. These were raised initially under glass from surface sterilized true seed, and sprayed at a rate suggested by the manufacturer for controlling late blight but twice weekly. At each sampling date four techniques were used in attempts to detect the bacteria on leaves, but they were found only once (8 September) with but one technique on a single sample from one of four replicate plots. Although the results raise doubts about the sensitivity of the techniques used, the finding of contamination of progeny tubers in the control plots must also raise doubts about the validity of claims made for high grade planting stocks and their freedom from bacteria. However, these preliminary results are of great importance in showing how initially bacteria-free stocks may be protected against air-borne contamination.

Table 4. Effects of copper oxychloride sprays on Erwinia carotovora infection of tubers (20/sample) harvested on three dates from plants grown from true seed (ex cv. Maris Piper) and the overall numbers of isolates identified as ssp. atroseptica (atr) or ssp. carotovora (car).

	Harvest date			E. carotovora ssp.	
	08 Sep	23 Sep	08 Oct	atr	car
Control	19	3	7	4	47
Copper Spray	0	0	1	0	2

Leach (1966) analysed soils from plots where potatoes had been sprayed against late blight with copper fungicides. The amount of "water extractable" copper was ca. 7 ppm and that of "replaceable" copper from ca. 20 to 90 ppm and these ranges variously affected growth and germination of Phytophthora infestans. In preliminary tests as part of the experiment cited above, the motility of ssp. atroseptica was stopped at concentrations of 10 ppm Cu and of ssp. carotovora at 5 ppm. At rates up to 100 ppm, Zn and Mn halted neither sub-species but, instead, Mn enhanced their motility especially that of the ssp. carotovora.

Mycorrhiza

The vesicular-arbuscular mycorrhiza (VAM) of potato have recently been almost ignored (Fox, 1981). The most important work, relating to the aims of CIP, is by Swaminathan (1979) and Swaminathan and Verma (1979). The first paper briefly reviews the role of VAM and phosphate uptake and demonstrated the benefit to potatoes of VAM in three latosols that strongly fix phosphorus and it was especially marked in a ferruginous soil that had the greatest affinity for phosphate. The second paper showed that potato VAM also enhances the uptake of zinc, an element widely deficient in Indian soils. The extreme sensitivity of true potato seed to P deficiency, demonstrated during this Conference in an experiment with (compost x sand) x (various ± NPK), was a most powerful illustrative argument for supporting VAM research in relation to CIP's true potato seed programme.

This brief contribution should be read in conjunction with the more extensive review (Fox 1981). Most work on potato pathology has concentrated on individual important diseases. Of those affecting the tuber, research for obvious reasons has concentrated on it as the harvested part. Work on broader aspects of the biology of these diseases should be undertaken. Approaches designed to promote general plant health and to investigate microbial associations of the plant may prove more rewarding than the magnifying glass approach focussing attention on one disease at a time. The potential for such rewards is exemplified by the work of Schroth and his colleagues (see Kloepper and Schroth, 1981); they have pointed the way for exploiting the rhizosphere by demonstrating that growth promoting 'antagonists' that increase yield can be established within the rhizosphere/rhizoplane community.

Acknowledgements

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DISTRIBUTION OF POTATO CYST NEMATODE PATHOTYPES (GLOBODERA spp., STONE) IN THE ANDES

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Summary

Potato cyst nematode populations from various Andean countries were identified. Species were determined by color changes during female development and morphometrics of second stage juveniles. Pathotypes were determined by nematode multiplication rate on standard differential clones.

Results indicated the presence of a new pathotype (P_2B) and the predominance of P_5A and P_4A pathotypes of Globodera pallida, respectively. This knowledge on variability and distribution of potato cyst nematode populations is very important for supporting and providing guidelines for breeding for resistance to the most common pathotypes present in the area.

Introduction

The potato cyst nematodes, Globodera spp., have co-evolved with their hosts (Solanum spp.) in South America and are widely distributed in the Andean region (Evans et al., 1975). The nematodes found in Europe, probably originated from just a small fraction of the genetical variability existing in the Andean populations. This would explain the presence in this area of certain pathotypes which have not been found in Europe (CIP, 1980). Therefore, identification of species and pathotypes is important to elaborate a control and management program in order to reduce or avoid their detrimental effects. Seventy three potato cyst nematode populations from several Andean countries were identified at species and pathotype level.

Results and discussion

Results confirmed early reports on species distribution and the existance of a demarcation line between the species G. rostochiensis and G. pallida at a latitude of 15.6°S. (Table 1). North of this latitude only G. pallida was found, while south of this line most populations examined were basically G. rostochiensis.

Table 1. Potato cyst nematode species of the Andean region.

Source and (number of samples)		Globodera species	
		G. rostochiensis	G. pallida
Chile	(2)	2 (2.7)[1/]	– (0.0)
Bolivia	(10)	6 (8.2)	4 (5.5)
Peru	(50)	3 (4.2)	47 (64.4)
Ecuador	(5)	– (0.0)	5 (6.8)
Colombia	(4)	– (0.0)	4 (5.5)
Venezuela	(2)	2 (2.7)	– (0.0)
Total number	(73)		
%	100	13 (17.8)	60 (82.2)

1/ Indicates the percentage of G. rostochiensis or G. pallida in the total number of populations examined.

Presence of G. rostochiensis in Venezuela could be considered as introduction from Europe until more information is obtained. On the other hand, although the presence of G. rostochiensis in Chile fits well with expected distribution, its origin would need to be more carefully investigated.

Although G. rostochiensis only represents 17.8% of the total number of populations examined, the most predominant or frequent pathotypes were R_1A and R_3A (Table 2). On the other hand G. pallida populations represented 82.2% and the pathotypes P_4A and P_5A were the most predominant (Table 3).

Table 2. Pathotype identification of potato cyst nematode populations Globodera rostochiensis

Source and (number of samples)		Pathotypes			
		R_1A	R_1B	R_2A	R_3A
Bolivia	(6)		1	1	4
Peru	(3)	1	2		
Chile	(2)	2			
Venezuela	(2)	2			
Total number	(13)	5	3	1	4
%	17.8 1/	6.8	4.2	1.4	5.5

1/ Percentage of total number of population studied.

Table 3. Pathotype identification of potato cyst nematode populations Globodera pallida.

Source and (number of samples)		Pathotypes					
		P_1A	P_2A	P_2B	P_3A	P_4A	P_5A
Bolivia	(4)			2	1	1	
Peru	(47)	1	2		2	18	24
Ecuador	(5)		1		1	3	
Colombia	(4)		1		1	2	
Total number	(60)	1	4	2	5	24	24
%	82.2 1/	1.4	5.5	2.7	6.8	32.9	

1/ Percentage of total number of populations studied.

These results (four pathotypes of G. rostochiensis and six of G. pallida) and the presence of a new pathotype of G. pallida (P_2B) indicate the existance of a wider genetical variability in populations of the Andean region than in other regions of the world.

Moreover, these results support the use of the P_4A and P_5A pathotypes of G. pallida as tester populations in the screening and breeding program for resistance to the potato cyst nematodes because of their predominance in the region.

Results indicate that our P_4A tester population from Peru is good nematode population to identify sources of resistance. When different P_4A populations from Peru and Ecuador were tested on the same previously selected sources, they also were resistant to the other populations and therefore the resistance could be more widely used as parental material in those area where pathotype P_4A predominates.

This represents a comparative advantage because it allow us to test, in advance, selected sources of resistance against the most predominant pathotypes occurring in the andean region.

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NEW SOURCES OF RESISTANCE TO GLOBODERA PALLIDA IN WILD SPECIES

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Summary

Breeders need a rather wide genetic base for solving the problem of resistance to pest and disease. Thus, it is important to search for and select new sources of resistance to different pathotypes of the potato cyst nematodes for broadening the genetic base of resistance and avoiding unexpected pathotype changes.

After seedling and tuber screening of 215 accessions of 61 wild potato species for resistance to P_4A and P_5A, the most common pathotypes of Globodera pallida, some clones with single or double resistance were selected. These clones showed a multiplication rate ranging from 0.16 times to 1.05 x and belong to the following species: S. bulbocastanum (2x), S. capsicibaccatum (2x), S. cardiophyllum (2x), S. gourlayi (4x), S. lignicaule (2x), S. megistacrolobum (2x), S. oplocense (6x), S. papita (4x), S. sparsipilum (2x), S. stenophyllidium (2x), and S. vernei (2x). The breeding potential of this promising wild germplasm is being investigated.

Introduction

The potato cyst nematode Globodera spp. is one of the most important pests in the temperate areas of the world where potatoes are regularly cultivated. In absence of effective and economic ways of controlling them, reliance has been placed on the discovery of sources of resistance and the development of cultivars with resistance to pathotypes of both species, G. rostochiensis and G. pallida. However, the discovery of potato clones resistant to potato cyst nematodes (Ellenby, 1954) was soon followed by the finding of nematode populations able to overcome this resistance (Quevedo, et al., 1956; Dunnett, 1961; Howard et al., 1970; Ross, 1972). Thus, breeders need a rather wide genetic base for solving the problem of resistance. Therefore, importance of searching for and selecting new sources of resistance requires broadening the genetic base of resistance and avoiding unexpected pathotype changes.

Results and discussion

1498 genotypes of 215 accessions belonging to 61 wild potato species were tested a-

gainst P_4A and P_5A pathotypes of Globodera pallida. These are two of the most predominant ones in the Andean region of Latin America.

The first evaluation to determine the resistance degree of the plant material under study was made by using the seedling pot test. Resistance of selected ones was confirmed twice by tuber pot tests.

Of the 987 genotypes tested 65.9 were eliminated because of susceptibility to the P_4A pathotype of G. pallida; 315 genotypes (21.0%) were discarded because of poor growth or no tuber production; 196 (13.1%) were selected for further evaluation. Results of first tuber test confirmed the resistance of 42 genotypes to P_4A and P_5A pathotypes respectively.

After the second tuber test, single or double resistance to G. pallida pathotypes was confirmed in twenty nine genotypes of fifteen accessions belonging to eleven wild potato species (Table 1).

Some of these potato species have been previously used in plant breeding. Additional species were found resistant to P_4A (Table 2) or both P_4A or P_5A pathotypes of G. pallida, representing new sources of resistance.

Table 1. Sequential screening of 1498 genotypes of 62 tuber-bearing Solanum species for resistance to potato cyst nematode, Globodera pallida.

Screening sequence	Species tested	Accessions tested	Genotypes tested
	R:S 1/	R:S	R:S
1) Seedling Test	51:11	144:71	511:987
2) Tuber Test (1st.)	15:16	20:31	42:154
3) Tuber test (2nd.)	11:0	15:0	29:0

1/ R = resistant; S = susceptible.

Table 2. Resistance to P_4A pathotype of Globodera pallida in some tuber bearing Solanum species.

Species and accession number	Genotypes (no.)	Origin
S. bulbocastanum (2x)		
PI 243345	1	Mexico
PI 243511	1	Mexico
S. cardiophyllum (2x)		
PI 255219	1	Mexico
S. gourlayi (4x)		
OKA 3802	2	Argentina
S. oplocense (6x)		
OKA 4498	2	Argentina
S. papita (4x)		
PI 283102	1	Mexico
S. stenophyllidium (2x)		
PI 255530	2	Mexico
PI 255529	1	Mexico

Research is being conducted to determine the breeding potential of selected genotypes of some of these species (e.i. S. bulbocastanum S. cardiophyllum and S. stenophyllidium) and the cultivated ones (Table 2). However, some wild Solanum species which are successfully being used in breeding for resistance possess combined resistance to both pathotypes of G. pallida. A low nematode multiplication rate ranging from 0.16 times to 1.05x which indicates a good degree of resistance to the tested pathotypes of G. pallida was found in some species (Table 3).

Further research is under way to determine the actual potential of these sources of resistance and their possible incorporation in breeding program for broadening the genetic base of resistance to the potato cyst nematodes.

Table 3. Nematode multiplication rate on selected tuber-bearing Solanum species presently being used in breeding resistance to P_4A and P_5A pathotypes of Globodera pallida.

Species and accession number	Clone number	NMR 1/ P_4A	NMR 1/ P_5A
S. capsicibaccatum (2x) WRF 1730	1	0.45	0.40
	2	0.32	0.41
	3	0.57	0.50
	4	0.71	0.31
	5	0.62	0.41
	7	0.69	0.25
S. lignicaule (2x) HHC 5113	6	0.63	0.21
S. megistacrolobum (2x) OKA 5775	4	0.58	0.68
S. sparsipilum (2x) HHC 4476	4	0.65	0.40
S. vernei (2x) OKA 4366	6	0.62	0.39

1/ Nematode multiplication rate = Final population/Initial population in eggs per pot.

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CULTIVARS RESISTANT TO BACTERIAL WILT AND LATE BLIGHT FOR THE HIGH AND MID-ELEVATIONS OF THE TROPICS

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Summary

Solanum phureja resistance has been effectively used to develop cultivars resistant to bacterial wilt caused by Pseudomonas solanacearum, by crossing with S. tuberosum cultivars resistant to late blight (Phytophthora infestans), thus having dual resistance. Further crossing with cultivars having adaptation to heat has resulted in resistance not only for the uplands but also for the mid-elevations in the tropics.

Introduction

High levels of resistance to bacterial wilt (Pseudomonas solanacearum) of the potato found in clones of Solanum phureja of the Central Colombian Collection (CCC) were utilized at the University of Wisconsin to initiate a resistance breeding program in 1967. Crossing was done initially with S. tuberosum ssp. tuberosum (Tbr), but because late blight resistance appeared necessary later, Mexican varieties were used which are essentially Tbr with S. demissum genes for resistance. The progeny were screened in growth rooms or greenhouses at Wisconsin and then distributed for field testing to tropical countries. Late blight resistance data was received from tests conducted at Toluca, Mexico. Progress was hampered by few reports of field performance being received (Rowe and Sequeira, 1972; Sequeira, 1979).

Materials and methods

Three hundred and sixty nine clones of 10 families bred for resistance to bacterial wilt and late blight were received in June 1970 from Wisconsin by the senior author who in collaboration with I. Herrera, a graduate student of the Universidad Nacional Agraria La Molina, conducted a screening program for both diseases at Huambos, Cajamarca Department of northern Peru at 2,450 m elevation. Herrera later continued to collaborate as a research officer of the Ministry of Agriculture of Peru (Herrera, 1972).

The small greenhouse grown tubers were planted in family rows in the Huambos field that had a severely wilt infected potato crop. Survivors were planted in a completely randomized block design with six repetitions of one plant each. Selections in this and subsequent tests were based on absence of foliar symptoms during three evaluations followed by observation of tuber symptoms at harvest and after storing for 20 days. In addition, tuber type and yield were recorded. Selected clones were planted in a randomized block design with 5 replications of 5 plants. Late blight was rated on a 1-5 scale in this last test (plots were sprayed for blight control during the first six weeks only).

Because bacterial wilt resistance is needed for potato production in locations with high temperatures (French, 1979) crosses were made at CIP between the best selections from the Peruvian program and Tbr clones showing adaptation to heat.

Seedlings were grown in flats under carefully controlled quarantine conditions and screened for late blight resistance. Cuttings made from the blight resistance clones were tested by soil infestation with isolate 013 (Huambos, Peru) in a heated greenhouse (25 - 31 ± 1°C range). Mother plants (not Pseudomonas inoculated) of resistant clones were retained and multiplied. A set of 33 clones in 11 families (5 tubers each) was sent to Sri Lanka, where the senior author was spending a year on sabbatic leave. A field test was conducted there with Mrs. M. Velupillai at the Rahangala Research Station, Boralanda, Badulla District (1350 m). Potatoes are grown in this district both on slopes and in paddy fields and bacterial wilt is a serious problem. Potatoes were first planted to test the inoculum potential. Because wilt was sporadic the randomized block design with 5 replications of one plant each included the alternate planting of a test plant and a susceptible check, Diamant variety. Observations were conducted in a similar manner to that described above.

Experimental results

Many of the clones in the families were lost due to factors other than bacterial wilt, such as excessive age of seed, pink rot, insect damage, etc. The G tuber replanting permitted the elimination of clones with low yield, "poor" tuber shape, high susceptibility to late blight and symptoms of wilt in the foliage or oozing at the eyes of tubers. A small proportion developed oozing from the eyes after storing, or had oozing from the vascular system when cut. From the third planting the 20 most promising bacterial resistant lines (BR-lines) were selected (Herrera, 1972). Unfortunately, Herrera was transferred to a different post and these clones changed hands three times until April 1974 when only seven remaining clones were handed to the Cajamarca Experiment Station Potato Program. During 1975 two sets of regional trials were carried out and on the basis of the assembled data the variety Caxamarca was named in January 1976 (Herrera et. al., 1977) and the following year Molinera (De la Puente et. al., 1977). These correspond to clones BR 63.74 and BR 63.65, respectively. Their pedigree being: Atzimba x A-1 ((316.3 (Phu 1386 x Phu 1339) x Katahdin)).

A survey of the areas of wilt infestation in the Departments of Huanuco and Cajamarca revealed that 13.5% of the area is planted to Molinera in the former and an estimated 20% in the latter. Caxamarca was grown by very few farmers, the reason being that under sub-optimal conditions it produces many small tubers and also that its immunity to late blight was overcome in 1978 and its field resistance is only moderate. Molinera lost its major gene resistance in 1979, but its field resistance is high, requiring only 2 or 3 fungicide sprays during the rainiest season. These results were predictable on the basis of late blight ratings from Toluca (Herrera, 1972).

A surprise in Cajamarca was to find two farmer selections extensively grown. BR 69.84, one of the seven final selections was being grown alone or most often as a mixture with Molinera, and is being called Molinera-2. Tubers of both are indistinguishable and plant type differs only in that BR 69.84 is about 10 cm taller, it matures later, and is susceptible to late blight. It is preferred for its culinary quality.

The clone designated as Amapola is of unknown pedigree and it must have been eliminated because of tuber type (deep eyes, elongated, occasionaly ramified). It was selected by Miguel Culpe, neighbour to our farmer collaborator, Mrs. Margarita Marreros Vda. de Alvarez. His selection criterion was blight resistance and high yield.

Of the 33 clones in the Rahangala test, nine in 6 families showed promise with up to 1 in 5 plants having wilt in the field and no tuber symptoms after harvest, versus heavy wilt incidence in some other clones and the check. These families had Molinera or Caxamarca as one of the parents.

Discussion

The results presented here are only a small part of the overall effort of CIP and about 20 National Programs to produce wilt and blight resistance for the tropics, both upland and lowland. The Peruvian example is the most developed, the Sri Lankan a relatively new one brought about by a strong commitment by its Department of Agriculture, and a strong collaboration initiated by CIP's Regional Program followed up by team work enhanced during working visits of Sri Lankan scientists to CIP-Lima and by that of CIP-Lima staff to Sri Lanka, and by formal training.

Many more tuber families involving other parents have been distributed, as well as clones developed earlier by CIP and Wisconsin. Some already show promise and varieties are in the process of being released in several countries (CIP Annual Reports).

The examples given lead us to conclude that the germ plasm CIP is distributing can result in the development of varieties in tropical countries in a few years. It took BR 63.65 ten growing seasons in 5 years to become Molinera. However, apart from the race or pathotype that determines the specificity of resistance, resistance adequate for a highland cool climate may be inadequate for the warmer, lower lands (French, 1979). The resistance which appears useful in the first trial reported here for a mid-elevation site in Sri Lanka, suggests that the same genes that give resistance for the highlands of Peru, when incorporated into a hybrid of which one of the parents is heat adapted, may provide resistance at warmer temperatures in this new gene combination. For resistance in even warmer lands new sources of resistance are being exploited (See Schmiediche et. al. in these proceedings).

Late blight resistance is important and the testing of crosses in the field at sites with a wide spectrum of "demissum" races as is the case of Toluca provided an adequate forecast of performance. However, the subsistence farmer may trade blight resistance for quality. The interplanting of Molinera and "Molinera-2" may be providing the advantage of a reduction in the rate of epidemic development as well as a maturity difference that allows the farmer a longer period during which to remove tubers from beneath the plants for his daily family needs.

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A PVY STRAIN THAT DOES NOT INDUCE LOCAL LESIONS IN CLONE A6

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A virus code named UF was isolated from a clone of S. tuberosum ssp. andigena growing in a screenhouse at the International Potato Center (CIP) facilities at the highland locality of Huancayo. Although observations under the electron microscope showed c. 750 nm flexuous filamentous particles like those of potato virus Y (PVY) and potato virus A (PVA), UF did not induce local lesions in clone A6 which is a diagnostic indicator plant for PVY and PVA (Köhler, 1953; de Bokx, 1972). Also, it failed to react serologically with diluted antiserum to PVY^0. Three groups of PVY strains are recognised: PVY^C, PVY^0 and PVY^N all of which have the same antigenic properties (Bokx et al., 1975). Rozendaal et al., (1971) and Bokx et al., (1975) reported that a deviating strain of PVY^C (PVY^C-Gl) isolated from the cultivar Gladblaadje in The Netherlands had a negligible relationship with other strains of PVY and Calvert et al., (1980) showed that PVY^C-Gl was very similar to strain PVY^C-AB from Northern Ireland. When UF was tested against antiserum to PVY^C-Gl it gave a strong reaction. Therefore, a detailed study was started to determine the relationship of UF to PVY strains.

The most typical symptoms induced by UF in indicator hosts and wild potatoes were veinbanding in Nicotiana glutinosa and N. occidentalis, mosaic and leaf deformation in Solanum chancayense, local necrotic spots and systemic necrosis in S. demissum Y and partial vein necrosis of leaf under

sides in potato clone A6. Primary symptoms in potato cultivars Atzimba, Atlantic, Kennebec, Norland, Radosa, Wauseon, Clavela, Maria Tropical and Tomasa Condemayta were mainly mosaics or systemic clorotic blotches.

Secondary symptoms also included premature senescence of lower leaves with formation of green spots or rings plus partial vein necrosis of the leaf undersides. When UF, PVY^C-Gl and PVY^C-R were inoculated by grafting to cultivars King Edward, Maris Peer, Pentland Dell and Pentland Crown, PVY^C-R induced a typical hypersensitive reaction consisting of necrotic spots and systemic apical necrosis in cv. King Edward which carries the hypersensitive gene Nc (Cockerham, 1943; de Bokx, 1972). In contrast PVY^C-Gl and UF both induced systemic chlorotic spots but no necrosis in this cultivar. Cvs. Maris Peer and Pentland Dell both reacted hypersensitively to UF and PVY^C-Gl but only Maris Peer gave a similar response to PVY^C-R. Cv. Pentland Dell reacted with chlorotic spots and mosaic. In comparative tests by mechanical inoculation to three Solanum spp., PVY^O, PVY^C-R, PVY^C-AB and PVY^C-Gl all produced local necrotic spots in S. chacoense and S. demissum P.I. 230579 hosts which have been reported to react with local lesions to PVY (Bokx, 1974; Webb and Wilson, 1978). In clone A6 only PVY^O induced typical local lesions reported for this virus (Köhler, 1953; de Bokx, 1972). PVY^C-R, PVY^C-Gl and PVY^C-AB all infected clone A6 without causing symptoms in inoculated leaves but the latter two isolates produced the same systemic vein necrosis of leaf undersides as did UF.

Observations under the electron microscope of sap preparations revealed the presence of flexuous elongated rods similar to those of PVY with a normal lenght of 760 nm. Infectivity in N. occidentalis sap was lost by diluting to 10^{-6} but not 10^{-5} in distilled water, by heating at 60 C but not at 55 C, and by storage at about 20 C for 3 weeks.

In serological comparisons in microprecipitin tests using purified antigens and 4 different antisera it was found that UF, PVY^C-AB and PVY^C-Gl were closely related. Similarly PVY^O, PVY^C-R and PVY^N were closely related, however the relationship of the first group of three viruses and the second group was distant. These results agree very closely to those reported by Calvert et al. (1980) when they tested isolates PVY^C-AB and PVY^C-Gl.

On the basis of the data presented, UF, should be considered as a new potyvirus from potato, because unlike PVA it is very stable, it does not infect S. demissum A and its serological relationship to PVY is distant. Similarly, unlike PVY, the type of symptoms it causes in potato cultivars are quite different to those caused by PVY and the serological relationship to this virus is distant. Because of the similarity of PVY^C-Gl and PVY^C-AB to UF they should be considered as closely related isolates of the same potyvirus.

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PYRETHROID INSECTICIDES AND APHID REPELLENTS AS MEANS OF CONTROLLING POTATO VIRUS Y

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Summary

In laboratory tests with apterous Myzus persicae, deltamethrin (0.001% a.i.) on infected leaves decreased transmission of potato virus Y (PVY) by S (insecticide-susceptible) and R_1 (moderately-resistant) aphids by 50-60%, but less by R_2 (strongly-resistant) aphids. In addition, deltamethrin-(0.01% a.i.)- sprayed plants were less infected than unsprayed plants (40-50% reduction) by viruliferous apterae. The repellent polygodial (0.1%) diminished acquisition of PVY by about 80%, irrespective of the insecticide-resistance status of the aphids.

Introduction

Non-persistent aphid-borne viruses such as potato virus Y (PVY) are among the most difficult pathogens to control because vectors need only brief probes to acquire virus or to inoculate healthy plants. Systemic aphicides consequently afford little protection. Although several aphid species can transmit PVY, the cosmopolitan species, Myzus persicae, is perhaps the most efficient and important vector.

Up to the present time chemical control of PVY has been achieved only by mineral oil sprays which appear to interfere with the transmission process itself (Simons and Zitter, 1980). As alternatives we are investigating the ability of pyrethroids to act sufficiently quickly by repellency (Ruscoe, 1977), knockdown (Briggs et al., 1974) or otherwise, to interfere with transmission (Gibson et al., 1982a) as well as the effects of some non-insecticidal aphid repellents/antifeedants (Gibson et al., 1982b). Field strains of M. persicae resistant to organophosphates and which also resist pyrethroids (Sawicki and Rice, 1978) are being examined to assess more generally the merits of the two approaches.

Materials and methods

Aphids. Three clones of M. persicae were used; S was organophosphate insecticide-susceptible, R_1 was moderately and R_2 was very resistant (Sawicki and Rice, 1978). Young adults reared on Chinese cabbage (Brassica pekinensis) were used in all tests.

Insecticides/aphid repellents. The pyrethroid deltamethrin (>95% pure) (Elliot et al., 1974) in ethanol was applied with a small brush; its commercial formulation Decis (2.5% e.c.: Procida, France) was dispersed in water and applied by a small hand-sprayer.

Polygodial, an insect antifeedant/repellent (Nakaniski and Kubo, 1977), was purified from foliage of the marsh pepper (Polygonum hydropiper) (Gibson et al., 1982b) and applied, in ethanol, with a brush.

Virus inoculation test. Boxes of 24 Nicotiana tabacum seedlings were either untreated (control) or sprayed with an aqueous emulsion of deltamethrin. Starved apterae made viruliferous by 2 1/2 min access to untreated infected N. tabacum leaves were confined in pairs on each plant.

Virus acquisition test. The test compound was applied to one half of a PVY^o-infected leaf (King Edward potato for deltamethrin, N. tabacum for polygodial) and allowed to dry: apterae previously starved for 3 hr were then allowed access either to the treated or to the untreated half for 2 1/2 min and subsequently were confined in pairs on individual N. tabacum seedlings to test whether they were viruliferous.

In both acquisition and inoculation tests, plants were sprayed with pirimicarb 24 hr after the aphids had been confined on them and afterwards kept in an aphid-free glasshouse for c. 15 days by which time all infected plants had developed symptoms.

Results and discussion

In the inoculation test (Figure 1) deltamethrin at 0.001% a.i. significantly diminished infection of healthy sprayed plants only by S aphids; at 0.01% a.i. it affected infection by all strains, even R_2 the most resistant. Comparable results were obtained in the acquisition test (Figure 2) where again only the larger dose (0.1% a.i.) greatly reduced acquisition by R_2 aphids. Most aphids on treated infected leaves showed signs of paralysis during the short exposure period, but they recovered on the untreated seedlings to which they were transferred and 24 hr later had similar survival to unexposed aphids. In a similar experiment R_1 aphids allowed access for 5 min to leaves of potato plants growing outdoors and treated 3 wk previously with deltamethrin (0.001%) still infected 50% fewer plants than aphids from untreated leaves ($P < 0.001$).

In the acquisition test (Figure 2), polygodial at 0.1% was the most effective

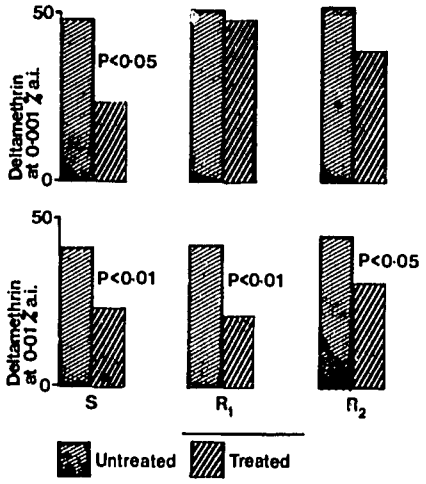

Figure 1. Percentages of infected N. tabacum plants sprayed with deltamethrin before exposure to viruliferous S, R_1 or R_2 M. persicae.

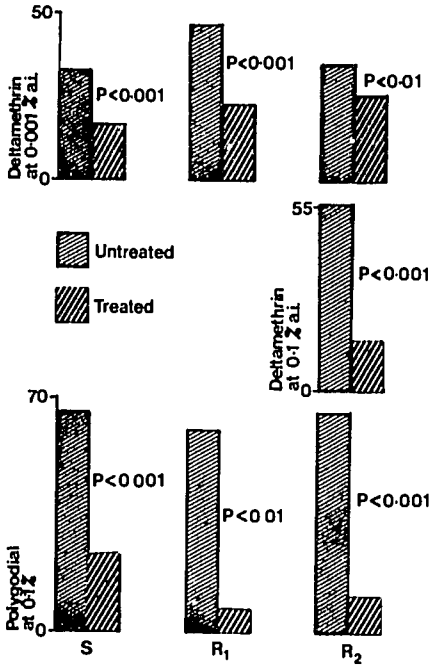

Figure 2. Percentages of N. tabacum plants infected by S, R_1 or R_2 aphids from treated or untreated infected leaves.

treatment examined. Significantly, it affected S, R, and R_2 strains about equally. Even at 0.02%, acquisition by R_1 aphids was diminished by about 50%. Racemic polygodial has now been synthesized at Rothamsted and preliminary results indicate that it has activity similar to the natural product.

These results demonstrate two novel approaches to the control of potato virus Y. Response to exposure to deltamethrin is sufficiently rapid to hinder transmission, by viruliferous aphids, at both the pick-up and inoculation stages of transmission. However, insecticide resistant (R_2) aphids are less readily affected which could be a disadvantage if R_2 aphids become dominant through the use of organophosphates. In contrast, the non-insecticidal compound polygodial hindered acquisition of PVY irrespective of the insecticide-resistance status of the aphid.

These results are sufficiently promising to justify the use of such compounds in establishing the principles of controlling virus transmission with behaviour controlling chemicals in the field.

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INHERITANCE OF THE RESISTANCE TO ROOT-KNOT IN POTATOES AND ITS COMBINATION WITH BACTERIAL WILT

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Root-knot of the potato, a disease caused by Meloidogyne spp., is known to occur not only in a number of tropical countries but also in some temperate ones. Bacterial wilt (Pseudomonas solanacearum) is another disease that affects the potato when it is grown in warm temperatures. Damage is increased when both diseases are present. Research in these two diseases has increased recently due to the interest in extending the growing area of this crop to the lowland tropics.

In root-knot the main effort has been in the search for sources of resistance to M. incognita, M. javanica, M. arenaria, M. hapla and recently to M. chitwoodi. Accessions belonging to 35 tuber-bearing species have been reported as resistant to one or more of the 4 more common species of Meloidogyne attacking potatoes, (Madamba, 1978). Some of the accessions of Solanum sparsipilum have been reported to have high levels of resistance to root-knot and bacterial wilt (Anonymous, 1979). Thurston and Lozano (1968), reported Solanum phureja as the first source of resistance to Pseudomonas solanacearum that gives adequate protection in the field, (Thurston, 1968). In 1973, a program was initiated at Cornell University in order to incorporate the resistance of Solanum phureja to bacterial wilt into the Cornell andigena breeding material. Crosses were made between Cornell andigena clones resistant to Phytophthora infestans and tetraploid clones resistant to P. solanacearum in an attempt to combine the resistance to both diseases in the andigena population. The seedlings of those crosses were screened in the greenhouse for general resistance to P. infestans. Cuttings from the resistant lines were rooted in vermiculite in a moist chamber. The rooted cuttings were inoculated with race 1 of P. solanacearum. Tubers of the clones resistant to both diseases were sent to Colombia, Costa Rica, and Peru for field tests. Four cycles of selection have been completed with this material, not only trying to combine resistance to both diseases, but also to incorporate resistance to viruses (mainly PLRV, PVY, and PVX), heat tolerance, tuber quality and adaptability to the lowland tropics (Plaisted et al., 1979).

The objectives of this investigation were:
- to determine the inheritance of the resistance to M. incognita, M. javanica, and M. arenaria, at diploid and tetraploid levels;
- to combine and increase frequency of resistance to the three species of root-knot in tetraploid progenies;
- to combine the resistance to the three species of root-knot with resistance to bacterial wilt.

Materials and methods

The source of resistance used for root-knot and bacterial wilt was Solanum sparsipilum. Solanum phureja was also used as a source of resistance to bacterial wilt (neo-tuberosum clones). The pedigrees of the clones used are the following:

Family	Parentage	N° of clones	Ploidy level
A442	Sps (phu x H. tub.)	7	24
A443	Sps (phu x H. tub.)	2	24
	Neo-tuberosum	12	48

Reciprocal crosses were made between resistant and susceptible clones at the diploid level and from 90 to 200 seedlings of each family or cross were tested for each species of root-knot. At the tetraploid level one clone resistant to the three species of root-knot was selfed and pollinated with a bulk of pollen collected from pollen of the neo-tuberosum population. Five hundred seedlings of these two families were tested for each of the 3 species of root-knot. The tests were conducted in the greenhouse at a temperature of 28°C, using seedlings or cuttings transplanted in 5 cm plastic pots filled with a 1:1, soil:sand mixture. One week after transplanting, the pots were inoculated with 5000 eggs of the desired species of Meloidogyne. The readings were made 55 - 60 days after the inoculation using the following scale:

0	= 0	galls or egg masses
1	= 1-2	galls or egg masses
2	= 3-10	galls or egg masses
3	= 11-25	galls or egg masses
4	= 26-100	galls or egg masses
5	= over 100	galls or egg masses

For the bacterial wilt test, three cuttings of each genotype were rooted in vermiculite in a 17°C greenhouse. When the cuttings were rooted, one-third to one-half of the terminal leaflets of three successive leaves per plant were sheared off with a pair of scissors. Between each cut, the scissors were dipped in a cell suspension of race 1 of Pseudomonas solanacearum. After the inoculation, the cuttings were transferred to a 30°C growth chamber. Five days later, evaluations were made using the following rating system:

0 = no wilt
1 = one leaf wilted
2 = two or three leaves wilted
3 = one third to two thirds of the leaves wilted
4 = three of the top five leaves wilted
5 = all leaves wilted

For both diseases, plants with a rating of two or less were considered resistant.

Results

Resistance in diploids:

M. incognita: Fourteen families were tested with a total of more than 1400 seedlings. The results of the chi-square test indicate that there is no maternal effect in the inheritance of the resistance to M. incognita. The hypothesis that best fits the observed ratios (Table 1) requires that 3 or 4 dominant genes be present to obtain a rating of two or less.

M. javanica: A total of 1147 seedlings were tested from 12 families. As in M. incognita no significant maternal effect was found in the inheritance of the resistance to M. javanica, present to obtain a rating of two or less. The hypothesis that best fit the observed proportions require that 3 dominant genes be present to obtain a rating of two or less.

M. arenaria: Twelve families with a total of 1624 seedlings were tested with M. arenaria. There were indications of maternal effects in the inheritance of the resistance to this species of root-knot. The hypothesis that best fit the observed proportions require that four or five dominant genes be present to obtain rating of two or less. Four genes are necessary when the resistant clone is used as female and five genes when the resistant clone is used as male.

The number of genes found at the diploid level for the three species of root-knot, were confirmed for the results of the self and testcross analysis at tetraploid level.

Resistance in tetraploids to root-knot:

Crosses between the diploid clones resistant to the three species of root-knot and the neo-tuberosum clones produced 268 tetraploid clones, 75 of them were resistant to M. incognita, 46 resistant to M. javanica and 60 resistant to M. arenaria.

The clones most resistant to the three species of root-knot were intercrossed in order to combine the resistance to the three species. Of these crosses 460 seedlings were tested for resistance to the three species. Of the total number of seedlings tested (Table 2).

Table 2. Percent of resistant seedlings to the three species of root-knot, in progenies of crosses between resistant parents.

Nematode species inoculum	Percent of seedlings resistant to		
	M.j.	M.i.	M.a.
Av. 12 families	73	95	71
M. javanica (M.j.)	-	87	100
M. incognita (M.i.)	91	-	100
M. arenaria (M.a.)	83	83	-

73% were resistant to M. javanica, 95% to M. incognita, and 71% to M. arenaria. Of the 73% resistant to M. javanica, 91% were resistant to M. incognita and of this 91%, 83% were also resistant to M. arenaria. Of the 95% resistant to M. incognita, 87% were resistant to M. javanica and 83% of these were resistant to M. arenaria. All of the clones resistant to M. arenaria thus were also resistant to the other two species of root-knot. In total, 165 clones resistant to the three species were selected.

The inheritance studies and the results of testing more than 800 clones, showed the following genic relations between the three species of root-knot:

A	B1B2		M. javanica
	B1B2	C1C2	M. incognita
A	B1B2	C1C2	M. arenaria

Clones resistant to any species of root-knot must have the genes B1 and B2. Clones resistant to M. javanica or M. arenaria also possess the gene A. Clones resistant to M. incognita or M. arenaria possess the genes C1 or C2. The presence of both C1 and C2 increases the level of resistance to the latter two species. The five genes that control resistance to M. arenaria include three genes responsible for resistance to M. javanica and four for resistance to M. incognita.

Combination of resistances to bacterial wilt and root-knot:

Three clones of the families A442 and A443 resistant to both diseases were crossed with the 12 neo-tuberosum clones resistant to bacterial wilt. The seedlings which resulted from these crosses were tested for bacterial wilt and root-knot. Of the total number of seedlings, 35% had a rating of two or less for bacterial wilt. Sixty percent of those seedlings were resistant to the three species of root-knot. Intercrosses between the clones resistant to both diseases were made and their progenies were screened for bacterial wilt and root-knot. In this second cycle of selection, 51% of the seedlings tested were resistant to bacterial wilt in comparison with 35% in the previous cycle. In total, 78 clones resistant to bacterial wilt and the three species of root-knot were produced.

Table 1. Observed and expected reaction of diploid hybrid progenies to M. incognita and proposed genotypes of parental clones.

Cross and proposed genotypes			Resistance:Susceptible ratio		
			Observed	Expected	X
A442-17	X C181-2	aaBbccdd	109:65	109:65	0.00
AABbCcDd	X C181-4,W5337.3	AaBbccdd	144:101	153:92	1.41
"	X USW 973	aabbccdd	43:40	42:41	0.01
A442-4	X C183-4	aaBbccdd	108:68	110:66	0.09
AABbCcDd	X C184-15	aaBbccdd	126:90	135:81	1.60
"	X W5337.3	AaBbccdd	125:74	124:75	0.02
A443-2 aaBbCcDD	A443-2 X C181-4	AaBbccdd	141:63	142:65	0.09

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DISCREPANCY BETWEEN TESTING SEEDLINGS AND TUBERS IN PROGENY SCREENING FOR RESISTANCE TO POTATO CYST NEMATODE GLOBODERA PALLIDA

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Abstract

Five thousand seeds of 26 different progenies involving clones 702535 and 70269B resistant to race P_4A of Globodera pallida were divided into 3 lots to be tested for resistance as follows: seedlings inoculated with an egg suspension; seedlings inoculated with cysts; and tubers exposed 30 cysts each. The methods of seedling inoculation employed gave similar proportion of resistant plants. Plants first grown to tubers and then tested gave half as many resistant selections as the seedlings, and when tubers obtained from resistant seedlings were retested, 75% were

reclassified as susceptible. Nongenetic factors related to root physiology and morphology may be responsible for the higher rate of resistant segregates in seedlings.

Introduction

Inoculating plants with cyst nematodes in the seedling stage is undoubtedly the fastest method to obtain resistant segregants and gives excellent results with progeny of plants which are segregating for major Gene H_1 and race R_1A of Globodera rostochiensis (Huijsman, 1955). Results with G. pallida on the other hand are variable, (Howard and Fuller, 1975; Forrest and Holliday, 1979). The intention of this study was, to see if progenies segregate consistently when different inoculation methods are utilized and, to compare tests on seedlings with those on tubers. The progenies utilized for this were different crosses of two new sources of resistance to Globodera pallida race P_4A, identified in CIP's germplasm collection: 702535 (Sipacanchi) and 702698 (Atacama) both native varieties from Southern Bolivia. The multiplication rates of nematodes in these parental clones given in final population/initial population ratios (Pf/pi) averaged 0.5 for clone 702535 and 1.4 for clone 702698 over 2 experiments where the Pf/pi ratio of "Renacimiento" (the control) was 14.

Progenies were grouped as follows: Group A, clone 702535 crossed to 14 different P_5A resistant clones; Group B, the same clone 702535 crossed with 12 different susceptible clones; Group C, clone 702698 crossed to 7 different resistant P_5A selection; Group D, the same clone 702698 crossed to 9 different susceptible selections; and finally, Group E, only 1 progeny of clone 702535 crossed with clone 702698 (Table 2).

Seeds of each progeny were divided into 3 lots to be tested with different methods, as follows:

A. Inoculation with 30 cysts per seedling at the seedling stage, 15 days after transplanting.

B. Inoculation with 4000 eggs per seedling at the seedling stage, 15 days after transplanting.

C. Inoculation of tubers with 30 cysts each. Tubers were obtained by harvesting seedlings which had been transplanted into the field. All plants rates as resistant in the first test were retested in a standard pot test. Plants with less than 5 females per root ball were considered resistant.

Results and discussion

Results of the two seedling inoculation methods are given (Table 1). Females became visible on those seedlings inoculated with the egg suspension 20 days later than those inoculated with cysts. Final evaluation of seedlings inoculated with an egg suspension was carried out 100 days after inoculation. In contrast, seedling inoculated with cysts were evaluated for the first time at 60 days and the final evaluation was carried out at 80 days. Segregation for resistance was 21.0% for seedlings inoculated with the egg suspension and 22.5% for seedlings inoculated with cysts. There were no significant differences within families.

Data from both seedling tests were combined (Table 2). Although there was a large variation within families, overall results showed no effect on segregation of parents carrying genes for resistance to race P_5A. Resistance in clone 702535 seems to be controlled by fewer genes than in 702698. However, the sets of genes complement each other since the highest numbers of resistant plants were obtained when both resistant clones were intercrossed (Group E).

Seedlings of the same families were planted in the field and tested for resistance as tubers after harvest. These tests (Table 3) showed a much lower segregation rate for resistance. The percentages were about half those of seedlings. However, the higher resistant segregates of clone 702535 were maintained. Also, the proportion of resistance resulting from the intercross of both clones Group E remained high.

When tubers obtained from resistant seedlings were inoculated a second time with the same nematode population, a very high proportion (Table 2) showed susceptibility. In this retest only 190 plants rated resistant. It became evident that seedlings showing even as few as one female must be discarded and only those with no visible females should be rated resistant. This more rigorous selection criterion lowered the percentage resistance from 22% to 13% bringing it closer to the results of the tuber test.

Seedling tests are useful in discarding large proportion of susceptible plants and also are good indicator of resistant gene frequencies. But, care must be taken to confirm the resistance for each clone in roots obtained from tubers. It appears that thin seedling roots prevent normal female formation early in the seedling stage; resulting in a higher proportion of resistant ratings.

Table 1. Comparison of two inoculation methods for seedling screening.

	Egg suspension		Cysts	
	No.	%	No.	%
Plants tested	2,675		2,975	
Resistant segregates at				
60 days	-	-	947	32
80 days	609	22	668	22.5
100 days	565	21	-	-

Table 2. Segregation for resistance in seedling test and a tuber retest.

Group (No. of seedlings)	Seedling test Resistant plants No. (%)	Tuber retest Resistant plants No. (%)	Incorrectly classified %
A (1380)	78 (27.4)	96 (6.95)	74.6
B (1480)	312 (21.6)	49 (3.3)	84.2
C (913)	169 (18.5)	12 (1.3)	92.8
D (1174)	186 (15.8)	0 (0)	100.00
E (81)	62 (76.5)	33 (40.74)	46.7

Table 3. Segregation for resistance in tuber tests.

Progeny groups	No. tested	Resistant No.	Resistant %
A	106	15	14.0
B	50	9	19.0
C	82	7	8.5
D	219	12	5.5
E	30	13	43.0

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SEED TUBER PROGRAMS FOR THE YEAR 2000

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In a normal flush out system of seed tuber production there are two basic operations. Firstly nuclear stock is maintained in a "disease-free" condition, with regular testing for known pathogens. Secondly, each year a fresh lot of pathogen-tested tubers are taken from the nuclear stocks and propagated until numbers are great enough to supply farmers with certified seed for just one year (Slack and French, proceedings of this Congress).

Rapid propagation may fit into such schemes as follows: rapid propagation either in tissue culture or in a properly organized screenhouse or glasshouse is protected propagation. That is to say, there should be little chance of reinfection during propagation. Thus the pathogen-tested material is maintained in its original state of health during rapid propagation.

The main restriction to the use of rapid propagation is cost. Figures presented in Goodwin (1980) would suggest that up to and including the planting of cuttings, the total labor input for most methods of rapid propagation is about one manhour per 40 to 50 cuttings. The most labor efficient use of cuttings is in the production of tubers in pots in a protected screen or greenhouse, where under optimal conditions (temperatures close to 21°C, long days, good nutrition), up to 1 kg of tubers can be produced per cutting in 4 months.

Short days and lower temperatures lead to the much faster production of low tuber yields. Tubers can be produced from leaf-bud cuttings (Quevedo et al., proceedings of this Congress) within 4 weeks, but are small and frequently show extended dormancy. All considered, it would be difficult to produce more than 20 kg of tubers/manhour of total labor. At Australian rates this would give a labor cost of at least $ 0.50 kg of tubers. Glasshouse space costs approximately $ 100 m^2, say $ 5 kg of tubers for construction, plus running costs. All in all seed produced under protected propagation will cost at least ten times (on a per kg basis) that produced in the field, under Australian conditions. In tropical countries, at mid elevations, costs may well be lower.

What advantages of protected propagation might offset its high cost? The primary advantages are faster introduction of new cultivars, but more important, reduced field exposure during propagation in the early stages of a flush out system. In traditional schemes the tubers are in the field for five years between the pathogen-tested nuclear stock stage and being sold to the farmer as a certified seed. The first three years of this propagation are usually at specially selected foundation seed farms, where there is least probability of reinfection of seed. Seed is propagated roughly 500 fold over this period. The final massive propagations occur at the seed potato farms. The main opening for the use of protected propagation is to reduce the number of years plants are exposed at foundation farms from three to one or even no years.

Two criteria will be relevant in deciding whether or not to use protected propagation. Firstly does extended field exposure at the foundation stage lead to reinfection, and a fall in seed quality? Where there is doubt it would be useful to examine this experimentally--to compare seed tubers which have spent 0, 1, 2, or 3 years at the foundation farm, all spending 2 years at the certified seed farms. If all give similar yields of good quality ware potatoes, then there is no justification for routine use of protected propagation in the seed scheme. This may well be the situation in many temperate countries. However, I would suggest that such experiments would demonstrate real seed quality declines in many tropical and subtropical countries.

Secondly, just how expensive is it to establish and maintain the foundation farm? In a number of tropical countries, for example the Philippines and Sri Lanka, the foundation farm is very inaccessible, and a true estimate of maintenance costs, if added to the costs of foundation seed production, would probably show this is very expensive seed. In temperate climates the occurrence of soil-borne diseases such as powdery scab can prejudice the value of the foundation farm. In these situations it could well be far cheaper to maintain the nuclear stocks, and to propagate through the foundation stages at a more accessible location, close to the seed production areas.

Within the next twenty years I suggest that many countries will come to employ a scheme as follows. Nuclear stocks will be maintained as long term cultures, in a pathogen-tested state, using techniques such as that described by Estrada et al. (proceedings of this Congress). Each year material will be propagated, initially in a bulk tissue culture step, such as the shaken flask technique, followed by further steps in a screen or glasshouse, using a rapid, simple technique such as single node cuttings (Goodwin, 1981). Once enough cuttings are available these will be planted in pots in the protected environment, and let to grow to maturity. The resulting tubers will then pass to the field, being propagated there only one to three years before being sold to the farmer as certified seed. In such a scheme nuclear stock maintenance and foundation seed production will both occur under maximum protection from pathogens, and at a cost which in many non-temperate countries may be comparable to or even less than that of current seed tuber schemes.

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IMPROVEMENTS OF ROUTINE TESTS FOR POTATO VIRUS IDENTIFICATION

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Development of virus-resistant potato and appropriate cultural practices will reduce the relative importance of virus diseases in some parts of the world. The substitution, of well adapted, virus sensitive cultivars by new virus resistant ones is however a very slow process. This is especially true wherever potatoes are grown with the help of elaborated seed certification programmes. The introduction of the potato in hot humid tropical zones may bring new problems. Unknown viruses affecting the cultivated potato may also originate from genetically interesting wild species of Solanum, which are increasingly used in breeding programmes. It seems therefore reasonable to think that methods are still needed for the year 2000, which facilitate the diagnosis of unknown diseases, the screening for virus resistance in breeding programmes and the study of viruses and virus diseases on potato. The methodical approach depends on whether one looks for unknown or known viruses:

- In the first case, relatively few but important changes have marked methodology since nearly 100 years ago, when Adolf Mayer (1883) transmitted for the first time a plant virus from mosaic diseased tobacco plants by mechanical sap inoculation to healthy plants. Analytical ultracentrifugation techniques, light and especially electron microscopy and more recently analytical electrophoresis combined with biological tests using large ranges of virus indicator plants have been extensively used. Immediate important refinements of these methods are difficult to predict.

- In the second case, the identification of the known viruses, a more steady improvement of methods has been recorded over the last 50 years. Specific biological and especially a wide range of serological techniques (Van Regenmortel, 1981) have been developed. New important improvements include the enzyme-linked-immunosorbent assay (ELISA), immunoelectron microscopy (IEM) and very recently molecular hybridization techniques (Owens and Diener, 1981). ELISA will undoubtedly play a major role in future virus identification. The general techniques described for the detection of plant viruses by Voller et al., (1976) and Clark and Adams (1977) were extremely rapidly applied in all kind of diagnostic situations. Due to its high sensitivity, ELISA allows unequivocal identification of potato viruses, including potato leafroll virus (PLRV) and potato virus A (PVA), in extracts from potato leaves (Caspar, 1977; Maat and de Bokx, 1978a, b; Gugerli, 1978, 1979). Similar results with extracts from tubers are obtained when enough attention is paid to the virus localization (Gugerli, 1980) and to the quasi-latency of some virus infections, especially infections by potato viruses Y (PVY) and PVA, in dormant tubers. The virus can be reactivated by artificial rupture of tuber dormancy (Gugerli and Gehriger, 1980). ELISA is applied without any special equipment but also by using a wide range of technical aids (Gugerli, 1979) which then allow to carry out large-scale testing. ELISA is therefore more versatile than any other serological or physico-serological technique.

Research should now be strengthed on improvements of high quality test reagents and on the elimination of possible causes of non-specific reactions in order to use the full resolution capacity of ELISA under varying test conditions. Recent studies made in the author's laboratory indicate possible ways to reach this goal.

First, it was possible to investigate the use of monoclonal antibodies for diagnostic work, (Gugerli and Fries, 1981). Monoclonal antibodies were produced by Inotech Ltd., CH-5610 Wohlen, using cell fusion techniques (Köhler and Milstein, 1975; Fazekas de St. Groth and Scheidegger, 1980). Spleen cells from immunized mice were taken as a source of antibody-secreting cells of known specificity. These were fused with cells to produce hybrid cells, some of which secreted PVY-specific immunoglobulins. Unfused cells were eliminated under selective culture conditions and final antibody-secreting hybrid cells cloned by repeated subculture and dilution. Several clones of cells were found which secreted immunoglobulins reacting with nine different PVY isolates belonging to the strains N, O, and C. Some of the PVY isolates used in this work were kindly obtained from Dr. J.A. de Bokx, IPO, Wageningen, and from Dr. L.F. Salazar, CIP, Lima. Immunoglobulins produced by one particular clone with high and similar avidity towards all nine PVY isolates were purified and labelled for use in standard "double antibody sandwich" type ELISA (direct ELISA). The reactions with these PVY isolates were little discriminating and extremely fast (Fig. 1). No serological binding of conjugated antibodies was observed with samples from healthy plants. In addition to the complete virus specificity monoclonal antibodies seem to improve the simple form of direct ELISA for field diagnosis pur-

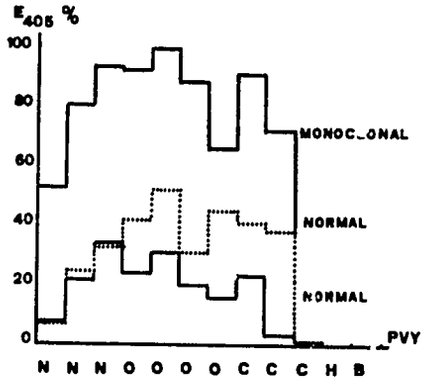

Figure 1. ELISA on PVY using monoclonal and traditional immune serum antibodies. Data: Mean extinction values are expressed in percentages of the highest value recorded in the experiment. Upper solid line: monoclonal antibodies, dotted and lower solid line: two sources of "normal" immune serum antibodies. Antigens: 10 PVY isolates belonging to strain N, O, and C, 9 of which are serologically related. Tested as crude extracts from infected tobacco (Xanthi). Dilution 1/20 in PBS-Tween-PVP. Incubation 16 hours at 6°C. H: healthy tobacco, B: buffer. Other test conditions: Coating 1 µg/ml, 4 hours at 30°C. Antibody-enzyme conjugate diluted 1/2000, 5 hours at 30°C. Substrate 1 mg/ml, 8 min at 20°C. Measured with Titertek Multiscan at 405 nm. Antibody purification, conjugation and buffers according to Clark and Adams (1977).

poses. The discrimination between serologically differing isolates observed in direct ELISA, probably due to the labelling of one part of the immunoglobulins with enzyme molecules, does not take place with carefully selected monoclonal antibodies. Cloned hybrid cells secreting immunoglobulins reacting specifically with various combinations of PVY isolates were also selected during this work. The outcoming results demonstrate for the first time unequivocal well defined serological differences between PVY strains and isolates of a particular strain.

Secondly, it was possible to analyse non-specific reactions occuring in ELISA with samples from various potato plant tissues. A fraction with an apparent molecular weight slightly below that of cytochrome C marker protein (MW 13000) was isolated by gel chromatography from potato tuber extracts. This fraction shows an extremely high affinity towards immunoglobulin-enzyme conjugates made either with alkaline phosphatase or horse-radish peroxidase. It binds also unlabelled immunoglobulins or enzyme molecules and interacts strongly with the polystyrene-moiety of which ELISA plates are made. The undesired reaction with the conjugate or the immunoglobulin was shown to be inhibited specifically by oligomers of N-acetyl-D-glucosamin. Further details will be published elsewhere. When purified Solanum tuberosum agglutin (STA), a phytolectin isolated from tubers, is used in ELISA, instead of plant extracts, important retention of immunoglobulin-enzyme conjugates occurs. The binding of the conjugate can also be inhibited by oligomers of N-acetyl-D-glucosamin, which is the specific sugar involved in the chemical interaction between STA and some glycoproteins. The reaction is the same if the conjugated antibodies originate from animal species which were immunized with a certain virus or not. Monoclonal antibodies from mouse behave identically. Other lectins, such as wheat germ agglutinin or Ricinus communis agglutinin, interact even more strongly and the binding is also prevented by specific sugars. It seems therefore that a lectin-like substance would be responsible for the main non-specific reactions observed in ELISA with samples from potato tissue. Remarkable differences in activity or concentration of this lectin-like substance are observed between various cultivars or between tubers of a given cultivar but grown under distinct conditions or of different physiological age. The lectin-like substance is also found in sprouts and to some extent in leaves, especially in very young ones. Other informations were obtained during this study. They will help to make of ELISA, together with high quality reagents, an extremely reliable technique for potato virus identification. Commercially available reagents facilitate and standardize its application and its worldwide distribution.

Development of appropriate technical aids for the small and large-scale use of ELISA can be predicted. Microprocessor controlled apparatus will allow nearly fully automatic processing of samples, execution of the test, and data analysis. Such equipment, already partially available, will be extremely useful to virologists involved in potato breeding. The presence of a particular virus in a potato plant tissue can then be monitored as easily as for example changing temperature in a glass-house. Much attention should further be paid to the development of very simple but efficient tools for the small and medium-scale application of ELISA under difficult field conditions.

The summarized data and ideas presented above describe some possible ways for the improvement of potato virus identification methods for the year 2000.

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POTATO PRODUCTION IN THE YEAR 2000 IN HUNGARY

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The climate of Hungary is less favorable for potato than the countries of West Europe.

Thirty years ago the per capita potato consumption was 100-120 kg. Nowadays it is 60-65 kg.

In the last decade special farms have been developed for production of potato, in which the potato land area is between 150-500 ha, and new production methods are used.

During the ten years 1970-1980, yields increased from 15 t/ha, to 30 t/ha in state owned and cooperative farms. We should like to increase the yields gradually to 50-60 t/ha in the year 2000'. Factors for increasing yield are the following:

New varieties. Ten years ago the yields of our varieties were 15-20 t/ha. The most important varieties are Desiree, Rosali, and Hungarian Rosa. These will be the main varieties in the next five years. We need more new varieties from the breeding program.

Fertilization. We need to use concentrated, compound chemical fertilizers, N, P, K, plus microelements and growth stimulating and regulating agents, etc. The time and system of fertilization is very important.

Soil cultivation. (Table 1). Potato requires deep soil cultivation deeper ploughing, and sub-soil cultivation. At the same time soil cultivation has to be coordinated with new methods of fertilization requiring new machinery.

Table 1. Potato yields are influenced by depth of ploughing.

Ploughing depth cm	Yield t/ha
20 - 25	23.2
26 - 30	25.5
31 - 35	24.8
35	28.2

Planting. In view of the new varieties we have to determine their planting depth, row distance, number of plants/ha, height of the primary and secondary ridge, the time of the ridge making, etc.

Plant protection. (Table 2). Nowadays in Hungary chemical plant protection is applied 10-11 times during the vegetation period. It is too expensive and dangerous. Accumulation of chemical compounds from plant protection has to be prevented in the soils. We need to use new chemical materials, new machines, and more effective biological, agronomical methods.

Irrigation belongs to technology of intensive potato production in Hungary with yields of 30-60 t/ha. We need further knowledge on the water demand of potato, as well as its water uptake mechanism etc.

Table 2. Rotation of potato yields to numbers of plant protectant applications.

Number of plant protectant applications	Yield (t/ha)		
	Chemical weeding	Control of late blight of potato	Control of Colorado potato beetle
1	21.1	18.7	24.5
2	25.7	23.9	27.1
3	38.5	21.4	24.6
4	-	23.1	25.1
5	-	27.3	22.5
6	-	28.8	-
7	-	29.9	37.0

USE OF COMPLEMENTARY DNA TO DETECT TOBACCO RATTLE VIRUS IN POTATO FOLIAGE

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Summary

Nucleic acid from the foliage of field grown potato plants with stem-mottle symptoms produced many local lesions resembling those of tobacco rattle virus (TRV) in inoculated leaves of Chenopodium amaranticolor. However, sap from these leaves was non-infective after two cycles of freezing and thawing and did not contain TRV nucleoprotein particles, suggesting that the symptoms were induced by NM isolates of TRV. TRV was identified unequivocally and was detected consistently by hybridization of nucleic acid from the potato leaves with DNA complementary to RNA-1 of the PRN strain of the virus.

Introduction

Although the association between potato stem-mottle disease and infection with tobacco rattle virus (TRV) was established by Rozendaal and Van Der Want (1948), a reliable diagnostic test for this virus in potato is still not available. Sap inocula from affected potato plants mostly induced only a few lesions, or none at all, in indicator plants such as Chenopodium amaranticolor, and attempts to culture readily multiplying virus isolates from these lesions were not successful (Cadman, 1959).

Molecular biological studies of TRV have shown that its RNA genome is in two parts (reviewed by Harrison and Robinson, 1978). The larger of these (RNA-1) can infect plants and induce symptoms on its own. However, no virus nucleoprotein particles are produced in such plants because the gene for TRV coat protein is in the smaller part of the genome, RNA-2; virus particles are produced only in plants infected with both RNA-1 and RNA-2. Sap from plants infected with RNA-1 alone is only weakly infective whereas nucleic acid preparations from such plants can be very infective (Sänger and Brandenburg, 1961; Cadman, 1962). Isolates of this type, which are known as NM isolates (Cadman and Harrison, 1959), occur in naturally infected plants of many species, and the failure of Cadman (1959) to obtain readily sap-transmissible virus isolates from stem-mottle affected foliage suggests that they also occur in potato. This paper provides further evidence on this point and describes a diagnostic test based on the use of DNA that is complementary in nucleotide sequence (cDNA) to TRV RNA-1.

Methods

Virus isolates. The PRN strain of TRV, obtained originally from potato in Scotland (Cadman and Harrison, 1959), was propagated in Nicotiana clevelandii and virus particles were purified and fractionated by a standard method (Kurppa et al., 1981). Potato foliage with stem-mottle symptoms was collected in field crops in eastern Scotland.

Nucleic acid extraction from leaf tissue. Nucleic acid was extracted essentially as described by Robinson (1973) and samples for hybridization experiments were further purified by precipitation from 2 M lithium chloride.

Infectivity assay. Inocula were rubbed on corundum-dusted leaves of Chenopodium amaranticolor. Nucleic acid inocula contained bentonite (0.6 mg/ml), 0.025 M sodium chloride and 0.005 M tris-HCl buffer, pH 8.0; plastic gloves were worn for inoculation.

Preparation and use of cDNA to RNA-1. RNA-1 was extracted with the aid of phenol from the long nucleoprotein particles of TRV strain PRN. ^{3}H-cDNA copies of RNA-1 were prepared as described by Robinson et al. (1980). Hybridization mixtures containing 0.1 ng cDNA and the nucleic acid extracted from 30 to 65 mg leaf in a final volume of 12 µl were incubated at 60°C in sealed capillaries. The percentage of cDNA rendered resistant to S1 nuclease by hybridization was assayed and was corrected for the S1 nuclease resistance of the cDNA alone (Robinson et al., 1980)

Immunosorbent electron microscopy. The procedure of Roberts and Harrison (1979) was followed, using antiserum to strain PRN of TRV.

Results

Infectivity assays

Foliage of stem-mottle affected plants was ground in 0.07 M phosphate buffer at pH 7 (1 ml/0.1 g leaf tissue), and the extracts subjected to two cycles of freezing (-20°C) and thawing. None of the resulting inocula was infective, although freezing and thawing has little or no effect on the infectivity of sap containing TRV nucleoprotein particles. Also, no TRV particles were detected in buffer extracts of the potato leaves by immunosorbent electron microscopy. However, all nucleic acid extracts from leaves of the same plants (1 ml/0.2 to 0.5 g tissue extracted) were infective, whereas extracts from symptomless plants were not (Table 1). These results suggest that the symptom-bearing leaves were infected with NM isolates of TRV.

Tests for hybridization with cDNA

A hybridization period of 3 h gave satisfactory discrimination between nucleic acid samples from symptom-bearing leaves and those from symptomless plants of all three cultivars tested (Table 1). When the period of hybridization with cDNA was increased from 3 h to 24 h, the percentage hybridization also increased. For example, after 24 h hybridization, the figures for King Edward plants 1 and 22 increased from 11 and 17% to 41 and 44% respectively; in comparison the figure for a sample from symptomless leaves increased from 1 to 2%. This suggests that borderline detections of TRV can be confirmed by increasing the hybridization period, and indicates that the lower hybridization figures obtained with samples from cv. King Edward probably reflect a lower content of TRV-specific RNA and not a major difference in nucleotide sequence between the virus isolates in King Edward and strain PRN.

Discussion

Because NM isolates do not produce virus particles, neither serological methods nor electron microscopy can be used for their identification, whereas the cDNA test proved sufficiently sensitive and reliable to detect infection in all field-grown plants tested. The test also enabled in-

Table 1. Infectivity of extracts of stem mottle-affected potato foliage and detection of tobacco rattle virus RNA-1 by hybridization to complementary DNA.

Variety and plant sampled	Leaf symptom	Infectivity of sap after freezing	Infectivity of leaf nucleic acid	Hybridization of leaf nucleic acid with cDNA
King Edward		1/	1/	2/
plant 1	+	0	167	11
plant 21	+	0	6	15
plant 22	+	0	175	17
Maris Piper				
plant 1	+	0	48	24
plant 4	+	0	71	31
plant 6	+	0	165	35
Pentland Crown				
plant 3	+	0	186	21
plant 6	+	0	770	27
plant 7	+	0	1,650	48
King Edward				
plant 23	0	0	0	3
Maris Piper				
plant 10	0	0	0	2
Pentland Crown				
plant 17	0	0	0	1

1/ Total lesions in 4 Chenopodium amaranticolor leaves.

2/ Percentage ^{3}H-labelled cDNA resistant to S1 nuclease.

fection with TRV to be distinguished from infection with potato mop-top virus, which can cause similar symptoms.

Methods that use cDNA seem likely to have numerous applications, and they have already been employed for detecting viroids (Allen and Dale, 1981; Owens and Diener, 1981). They should be suitable for other viruses which have RNA genomes but either do not produce nucleoprotein particles or possess particles that are unstable in tissue extracts. Moreover, if the sample preparation and hybridization assay can be simplified, cDNA methods may find applications in screening large numbers of samples for infection with any specified virus that has a RNA genome.

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EVALUATION OF POTATO LINES FOR RESISTANCE TO THE MAJOR SPECIES AND RACES OF ROOT-KNOT NEMATODES (MELOIDOGYNE SPECIES)

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Summary

Progenies of potato families, developed at the International Potato Center, that had segregated 70% or more resistant to a Peruvian population of Meloidogyne incognita were evaluated for resistance to major species and races of this genus: the majority of potato seedlings had resistance to one or more populations. Only 15% of the total population tested were susceptible to all Meloidogyne populations. 69% of the total progenies tested were resistant to 5 or more Meloidogyne populations, while only 5 plants had a high level of resistance to all populations.

Introduction

Susceptibility of potato to root-knot nematodes has been documented by serious losses in yield and in reduction of quality, especially in warm climates. Though some control can be achieved with nematicides and cultural practices, including crop rotation, utilization of resistant cultivars is more effective and practical.

Resistance to a Peruvian population of M. incognita was found in Solanum sparsipilum and S. chacoense (Jatala and Mendoza, 1978). A breeding program was initiated to transfer the resistance to cultivated tetraploid Solanum spp. (Mendoza and Jatala, 1978).

Since the potatoes developed in the breeding program at the International Potato Center are tested in different countries for their adaptability and resistance, it was necessary to test selected families for resistance to several important races and species of Meloidogyne that are cosmopolitan in distribution.

Results and discussion

Progenies of selected families of the fourth cycle of recurrent selection that had segregated 70% or more resistance to a Peruvian population of Meloidogyne incognita were evaluated at the International Meloidogyne Project Research Center at Releigh, North Carolina for resistance to the major species and races of the root-knot nematode. M. incognita (4 races), M. arenaria (2 races), M. javanica, and M. hapla were the eight populations selected for evaluation of 397 individual seedlings of eight CIP families. All seedlings that exhibited an acceptable degree of resistance (less than 10 galls per plant) for all root-knot populations were retested (Table 1). Seedlings with less than 10 galls per plant yielded fewer nematode eggs than comprised the original inoculum. Additionally, M. incognita race 1, M. arenaria race 2, and M. hapla were studied to see if a relationship exists between reproduction and the degree of galling. The reproductive ability or index or reproduction (IR) was determined by comparing the number of eggs produced on a test plant to that number produced on a susceptible control.

Table 1. Resistance (10 or less galls per plant) to several species and races of Meloidogyne in selected CIP breeding lines.

Families tested	Percent of plants resistant to 1/ M.i. Races 1	2	3	4	M.a. Races 1	2	M.j.	M.h.	C.r. 2/
378857	86	97	94	95	94	90	70	51	26
378875	78	77	74	84	83	74	72	30	22
378908	76	75	68	71	82	58	81	71	32
378911	69	82	88	95	94	54	86	38	18
378916	55	57	50	74	69	67	62	56	12
378924	80	86	81	100	81	86	90	70	43
378930	72	73	69	71	74	76	78	47	25
378950	81	68	60	82	70	72	72	63	30

1/ M.i. = Meloidogyne incognita
M.a. = M. arenaria
M.j. = M. javanica
M.h. = M. hapla

2/ C.r. = Combined resistance
Percent resistant to all species and races.

The majority of the potato seedlings had resistance to one or several populations since only 15% of the seedlings tested had gall production by all Meloidogyne populations. Of the plants, 69% had no gall production in response to five or more root-knot populations and only 5 plants had a high level of resistance (no galls) to all populations (Table 2).

Comparison of frequencies of the egg mass index (EI) of all seedlings shows that M. hapla differs from the other root-knot populations by exhibiting a lower response of resistance. The plants segregated only 52% resistant (less than 10 galls per plant) to M. hapla compared to 69-82% resistance to other root-knot populations. In response to the other root-knot populations, the potato seedlings had the

Table 2. High resistance (no galls per plant) to several species and races of Meloidogyne in selected CIP breeding lines.

Families tested	Percent of plants resistant to 1/ M.i. Races 1	2	3	4	M.a. Races 1	2	M.j.	M.h.	C.r. 2/
378857	61	83	86	89	83	42	41	30	0
378875	56	64	70	78	74	56	65	11	2
378908	63	62	57	60	76	34	80	41	3
378911	54	57	77	87	89	22	57	20	2
378916	31	44	36	58	49	36	56	32	0
378924	60	52	71	76	57	48	81	40	5
378930	45	60	47	55	45	62	71	18	2
378950	52	50	33	56	40	49	60	29	0

1/ M.i. = Meloidogyne incognita
M.a. = M. arenaria
M.j. = M. javanica
M.h. = M. hapla

2/ C.r. = Combined resistance (Percent resistant to all species and races).

highest segregation of resistance (82%) to M. incognita race 4. Segregation of resistance to the other root-knot populations varied from 69 to 73%.

Frequency of segregation of resistance ranked the CIP families as: 378924, 42%; 378950, 28%; 378908, 28%; 378857, 26%; 378930, 24%; 378875, 21%; 378911, 13%; and 378916, 12% of seedlings resistant (less than 10 galls/plant) to all populations. The former families appear to be more desirable prospects for selection and breeding.

After extraction of eggs from plants infected with M. arenaria race 2, M. incognita race I, and M. hapla, a strong correlation (R value = .96) was shown to exist between the EI and the IR. This relation validates the use of EI for rating the reproductive ability of root-knot nematode populations on the test plants. However, plants which had no galling were not immune since an average of 73 eggs were recovered from each plant. Highly resistant and immune plants cannot be distinguished on the basis of the EI.

Sixty-nine tomato cultivars evaluated by Hadisoeganda and Sasser (1982) appeared to have little resistance to M. hapla. The CIP families appeared to have no relationship between resistance to M. hapla and the other Meloidogyne species tested, suggesting an independent mechanism for resistance to M. hapla.

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A VIRUS ASSOCIATED WITH SYMPTOMS RESEMBLING PURPLE TOP WILT IN POTATO

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A virus disease new to potato and other plants was identified in the testing program of breeding for resistance to the potato leafroll virus (PLRV) on the eastern slope of the Andes at an elevation of 800 m. above sea level at San Ramon, Peru. The field was on the flood plain of a swift flowing river in the region of steep hills in the Chanchamayo valley in which tropical crops are normally grown.

The virus is presently called the Solanum Apical Leaf Curling Virus (SALCV).

Symptoms of SALCV on potato resemble those of unusually severe current season infection by PLRV or early symptoms of mycoplasma disorders such as stolbur or the purple top wilt disease associated with the asters yellows mycoplasma.

Symptoms of current season infection resemble PLRV in the early stages. Later apical rolling becomes much more pronounced and often strong anthocyanin pigmentation develops in the apical leaves beginning at the leaflet bases. Tuber borne infection may not be evident upon emergence. Often normal appearing leaves are produced at the lower part of the plant and later the apical portion begins to roll producing a plant with strong apical bunching. Internodes are often shortened, nodes enlarged, and aerial tubers or enlarged axillary leaf buds are formed.

First symptoms of graft inoculated potato plants are apical upright growth, cupping of leaflets, inward rolling at the leaflet bases with pink, red, to purple pigmentation at the bases and undersides (Figure 1). Frequently rolling is so severe that a knobby appearing terminal is formed. Leaves previously formed at the time of grafting remain normal but the recently expanded leaves under certain conditions, may have yellowing or clearing of the smaller veins.

Figure 1. Symptoms of SALCV on Huagalina stock grafted 41 days previously.

Tuber size is markedly reduced and when infection has been severe through one or more tuber generations, tubers may fail to germinate or may produce hair sprouts.

Symptoms of both tuberosum and andigena types of potatoes are essentially similar.

Rutgers tomato when graft inoculated may lack symptoms but when cut back new growth is deformed, stunted, and chlorotic. Vein yellowing is not common. Datura tatula responds to graft inoculation by strong systemic vein yellowing of newly formed leaves, severe deformation of leaves formed after grafting, and stunting. Nicandra physalodes responds by apical chlorosis, vein yellowing, and deformation following graft inoculation or when naturally infected in the field. Solanum nigrum and S. basendopogon naturally infected in the field may lack symptoms or symptoms are very mild. Such plants brought to the greenhouse may produce slightly deformed leaves with some vein yellowing.

SALCV was first encountered in the breeding program for PLRV resistance in the high jungle site at San Ramon. Plants from resistant progenies had been grown from true potato seed. Such seedlings were transplanted to the field at an early stage. Aphids and other insects were permitted to develop normally in absence of insecticides and PLRV carrying potatoes were spaced at internals to provide inoculum for natural field infection.

In 1981, tubers from representative lines, each tuber from an individual plant, were grown for observation. Of several hundred plants from such tubers, 20 were selected in the second tuber generation because of distinct symptoms resembling severe primary PLRV infection or mycoplasma diseases. Scions of these plants were grafted onto tomato stocks and there were no symptoms until formation of new growth after stocks had been severely cut back. New growth in 3 of the grafted stocks was severely distorted, chlorotic, and stunted. Grafts using these infected tomatoes as scions were made to Datura tatula which responded by marked yellow discoloration of veins in recent new growth followed by distortion and stunting. These symptoms were distinct from those of potato viruses previously reported on D. tatula or D. stramonium and an unusual virus or virus strain was suspected.

To determine the extent of infection of this new virus and to determine as well, natural infection of other viruses, single tubers each from an individual seedling plant in a similar resistance trial a year later (1982) were greenhouse indexed. Each plant was tested by enzyme-linked immunosorbent assay (ELISA serology) for PLRV and for potato virus Y (PVY). Plants with symptoms aberrant to either of these viruses were grafted to D. tatula or to tomato cv. Rutgers.

Of 250 plants so tested, 198 produced foliage sufficient for visual examination, classification as to virus symptom, and for ELISA serology. Only 50% lacked SALCV, PVY or PLRV and were considered healthy. PVY alone was present in 10% of the plants, PLRV alone in 30%, and

PLRV-PVY double infections 4.4%. SALCV had infected 11 (5.5%) of the plants with foliage.

SALC was ultimately identified in 29 plants (12%) by characteristic symptoms from potato scions grafted onto stocks of either or both D. tatula or Rutgers tomato. Symptoms of plants in which the virus was demonstrated are shown (Table 1).

Highest incidence of SALCV was in weak plants and those from hair sprouts, infecting plants with these symptoms to 36 and 59% respectively. SALCV occurred in 4 leafrolling plants as a single virus, in combination with PLRV in 4, and PLRV-PVY in 1 plant. SALCV-PLRV-PVY caused mosaic in 2 plants and SALCV alone caused mosaic and leafrolling in 1 plant. In these mosaic plants the presence of other mosaic producing virus was not determined.

Attempts to graft eyes of dormant tubers as scion grafts into nodes of tester plants failed. Although dormant tubers were not included in the number of positive SALCV isolations it is probable that at least some of these tubers were SALCV infected because in infected tubers with hair sprouts many eyes failed to sprout.

The virus has not been transmitted by the aphid, Myzus persicae. However, leafhoppers or white fly are suspected as being natural vectors. Graft transmission is the only method so far known to be successful. This is not completely successful as frequently second or third attempts to graft transmit are successful, even though earlier attempts had failed. Apparently the virus is phloem limited, existing in the entire plant in low concentration.

Table 1. Occurrence[1/] of SALCV in plants with several symptoms and in combination with PLRV or PVY.

Symptom	Number with				
	SALCV only	SALCV +PVY	SALCV +PLRV	SALCV +PLRV +PVY	Plants with symptom indicated (No)
Healthy appearing	0	0	0	0	100
Leafrolling	3	0	4	1	59
Mosaic	0	0	0	2	39
Leafrolling and mosaic	1	- [2/]	-	-	8
Weak plants	8	-	-	-	22
Hair sprouts	10	-	-	-	17
Dormant seed tuber	-	-	-	-	5
Total					250

1/ Number of plants in sample from field grown tubers.

2/ - Presence of PLRV or PVY not determined.

Purification has been successful following homogenization with 0.1M citrate buffer (pH 6.0) containing mercaptoethanol and Driselase, chloroform-butanol emulsification, polyethylene glycol precipitation, differential centrifugation, and sucrose density gradient centrifugation.

Virus particles are 19 x 52 nm in size consisting of 3 isometric units in a straight chain. Similar particles are present in purified preparations and in leaf dip extracts (Figure 2).

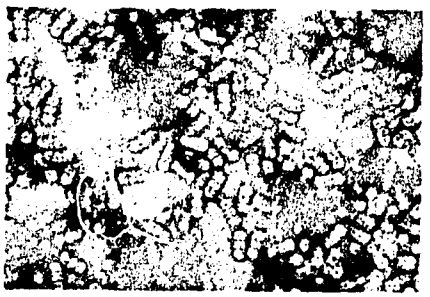

Figure 2. Purified preparation of SALCV virus. Particles consist of 3 isometric units in a straight chain 19 x 52 nm.

THE BREEDING POTENTIAL OF NATIVE ANDEAN POTATO CULTIVARS

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Summary

The potato germ plasm bank of CIP presently comprises about 6,000 accessions of clonally propagated primitive cultivars. This collection is considered to be the largest, most complete and most diverse sample of Andean cultivars.

The systematic evaluation of this collection to determine genotypic reaction to pests, diseases and adverse environmental factors has made available new sources of resistance to golden nematode, tuber moth, soft rot, PLRV, etc. Some cultivars with high dry matter and high total protein content have been identified in evaluations for nutritive attributes. Thus, a great breeding potential which is yet to be fully exploited exist in the native cultivars.

Introduction

Many native potato cultivars have been grown in the highlands of South American Andean countries for a long time under traditional agriculture conditions. Systematic classifications of samples of these cultivars have shown several taxonomic species involving a polyploid series as well as a large degree of intraspecific variability.

Most cultivated potato species have evolved as a result of natural intra- and interploidy hybridization involving not only cultivated species, but also some closely related wild species. It is highly likely that introgression also played an important role in part of their intraspecific diversification. This could have taken place when some cultivars were introduced into new areas of cultivation and they became sympatric with other new wild species. Gene flow was certainly favored by out-crossing, the growth of different and numerous cultivars in the same field, and the presence of wild species in and around potato fields.

As a result of the long evolutionary history, these cultivars are highly heterogeneous; have developed resistances and/or tolerances to a wide range of pathogens; and due to man-made selection they possess genetic components for adaptation and productivity under conditions of environmental stress. Therefore, this genetic diversity constitutes valuable material for the plant breeder.

CIP's cultivated germ plasm collection

Since 1972 the International Potato Center (CIP) has organized and managed a systematic collection of genetic diversity in the tuber-bearing Solanum species.

Until 1976 first priority was assigned to collection of native cultivars because they were in an alarming process of "genetic erosion." More than 13,000 clonal samples were assembled at CIP through donations from some national potato gene banks and from numerous collecting expeditions made throughout the traditional cultivation areas in Latin America. Identification of duplicate accessions has gradually reduced the collection to about 6,000 accessions. These are clonally propagated each year for further evaluations.

Taxonomic studies in this collection have shown a greater genetic diversity within each cultivated species than reported in other gene banks around the world (Ochoa, 1975; Jackson et al., 1977; Schmiediche, 1977; Tay, 1979; Huamán et al., 1980). For that reason CIP's collection is considered to be the largest, most complete and most diverse of Andean primitive cultivars in existence.

Evaluations of CIP's collection for desirable attributes

It is well established that valuable characters have already been identified in the cultivated potato species of South America (see revision by Howard, 1974). However, the availability of a large collection of native cultivars, the strategic location of CIP in the center of diversity of the potato, and the existence of more aggressive isolates or races of pathogens than those found outside South America, provides a unique opportunity to more fully evaluate the breeding potential of this valuable genetic reservoir.

A systematic evaluation of the Andean cultivars has been underway since CIP began, following a multidisciplinary approach involving scientists from the genetics, phytopathology, nematology, entomology, and physiology units. As much as possible, accessions possessing desirable attributes are re-tested.

Accordingly, more than 29,000 evaluations have been made and more than 3,500 of them have reacted with various degrees of resistance to the most important fungi, bacteria, viruses, nematodes, insects, and some environmental stresses affecting the potato crop (Table 1). The frequencies of resistant genotypes ranges from about 2% to 17%. Frequencies below 1% are obtained mainly in those traits where most of the data were taken on susceptible genotypes showing symptoms on naturally infested fields (e.g. smut and pink rot). On the

other extreme, frequencies higher than 20% are found when the screening was made using selected genotypes where preliminary field observations indicated some resistance (e.g. bacterial wilt, late blight). The actual frequencies will be modified once the process of duplicate identification is finished. In general, the frequency of partially resistant genotypes is much higher than those with high levels of resistance.

Further CIP studies on Andean cultivars carrying desirable attributes have shown remarkable results. For example, crosses between cultivars moderately resistant to the nematode Globodera pallida (International Potato Center, 1977) and to late blight (Estrada and Turkensteen, 1977) produced offspring with high levels of resistance to those traits. Two cultivars highly resistant to race P_4A of G. pallida were also resistant to many different populations from four Andean countries (International Potato Center, 1979). Eleven cultivars have been identified as highly resistant to three black wart populations which break the resistance of European race differentials (Soto, 1978). Numerous Andean cultivars have multiple resistance to pests and/or diseases. As of now, one accession is resistant to five different traits, seven accessions to four, 71 accessions to three and 14 accessions resistant to two traits.

Table 1. Data on evaluations conducted at CIP using native Andean cultivars.

Traits evaluated	Accessions evaluated N°	Accessions with some resistance N°	%
Fungus diseases			
Late blight	964	224	23.24
Pink rot	2,968	3	0.10
Common scab	927	64	6.90
Wart	1,622	66	4.07
Smut	329	2	0.61
Charcoal rot	2,383	46	1.93
Bacterial diseases			
Soft rot	226	48	21.24
Pseudomonas wilt	28	15	53.57
Virus diseases			
PVX	627	181	25.97
PVY	601	41	6.82
PLRV	1,112	27	2.43
Nematodes			
Globodera pallida	5,264	311	5.91
G. rostochiensis	1,252	213	17.01
Meloidogyne incognita acrita	3,938	643	16.33
Insects			
Phthorimaea tuber moth	2,871	404	14.07
Environmental stress			
Frost	341	76	24.63
Hail	3,932	1,319	33.55
Total	29,455	3,683	12.50

Cytogenetical evaluations in some Andean cultivars have identified new 2n-pollen producers. Out of 806 diploid cultivars studied, 55 produced 2n pollen (Chujoy and Iwanaga, 1982).

Nutritive quality studies of 840 native cultivars involving samples of all cultivated species have shown a significant but low negative correlation ($r = -0.248$ and $r^2 = 0.061$) between dry matter and protein content (Huamán, 1978). Dry matter content ranged from 25% to 38% in 414 accessions and the total protein content (dry weight) between 10% and 15% in 168 accessions. A total of 92 accessions have high dry matter above 25% and high protein content above 10%. Moreover, 35 andigena, 21 diploid and 16 triploid and pentaploid cultivars were identified with contents of 2.7% to 4.0% protein on a fresh weight basis.

It is expected that within native cultivars great variations in many other factors of importance in breeding have yet to be found. Among other potentially favorable traits are yield, length of tuber dormancy, storage qualities, flavor and cooking qualities.

Development of improved native population

Native Andean cultivars possess some undesirable characters that discourage their use in breeding because a series of backcrosses and cycles of selection are required for their elimination.

In order to promote more intensive exploitation by breeders of the rich genetic reservoir in these native cultivars, CIP is developing improved populations using Andean cultivars with known desirable attributes. The four main goals are: (1) to produce highly heterozygous and heterogeneous populations; (2) to reduce the tremendous genetic distance between primitive and advanced populations; (3) to concentrate and up-grade gene frequencies for desirable attributes; and (4) to combine desirable traits which are widespread over different accessions in the native cultivated gene pool (Huamán, 1980).

So far, 213 seed families have been obtained using single and bulk crosses of cultivars with resistance to the same pathogen; 175 of them comprise resistant material to eight single pathogens, one group of 28 and other of 10 seed families involve a combination of two and three different pathogens, respectively. Further screening of these hybrid seeds is to identify genotypes with higher gene frequencies for resistance to the pathogens involved.

Conclusion

Although several potato collections of native Andean cultivars exist in the world, most of them have been relatively deficient in intensive evaluations of their stocks. The focus of CIP systematic evaluation of native cultivars is on the need to make available new sources of valuable genes which could be readily incorporated into breeding stocks to solve present and future problems of the potato crop. The large number of evaluations made in a relatively short time has been largely possible because of the clonal maintenance of these cultivars at CIP.

Data clearly shows that a number of desirable genotypes have already been identified. Thus, a great breeding potential yet to be fully exploited for the benefit of mankind, exists in the native cultivars.

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VINE TYPE AND TUBER TYPE SELECTION IN A POPULATION OF NEOTUBEROSUM

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During the process of adaptation of Solanum tuberosum ssp. andigena to the conditions of northeastern U.S.A., selection emphasis was placed on tuber characters, yield, and disease resistance. The evaluation of the progress of this selection (Rasco, 1979; Muñoz, 1980) and the importance of this tetraploid source of germplasm in the context of potato breeding (Plaisted, 1972), point out its relevance for immediate utilization.

Vine characters have not been a subject for selection in Neotuberosum, although some descriptive studies reveal their importance when compared to the commercial potato, and may serve to provide a better understanding of the origin of ssp. tuberosum. Simmonds (1964) related large leaf size to long day "tolerance" and, in fact, some improvement in vine type has been observed during selection for tuber characters under long day conditions of Ithaca, New York.

The relationship of the tuberosum vine type to several characteristics of importance during a process of recurrent selection of the Neotuberosum material is discussed below. The first cycle of selection and parents for the second cycle are described. Correlations among characters, heritabilities and selection response estimates are also given.

Materials and methods

The seventh cycle of selection for tuberization was the base population from which a recurrent selection procedure was applied. Four groups of selected parents were intercrossed with bulk pollen from the same subpopulation: a vine type group (V) was selected only on the basis of vine characters, a tuber type group (T) received selection only for tuber characters as it was done in the previous cycles; a joint selection for vine and tuber type formed the (VT) group, and finally, a random sample from the base population with no further selection formed the (R) group. The number of clones participating in each intercrossing varied from 20 to 50 per subpopulation, and a selection pressure of 5% was applied to the 3200 seedlings transplanted to the field in 1980. Part of the seedlings were transplanted in completely randomized designs to estimate correlations among characters, variability of the material under selection and estimates of heritability. In 1981, selected clones from the two cycles of selection were planted in a completely randomized blocks design to compare between cycles and complete the observational studies. Four leaflet measurements, dissection and a general vine score were used to assess the vine type. Skin colour and type, distribution and number of eyes, flesh colour, shape, size, uniformity, yield and number of tubers were described using CIP descriptors of the potato. Abnormality such as unusual tuber shapes, secondary growth, stolons, cracks, hollow heart, internal necrosis and lenticels were also recorded.

The regression of mother-offspring was used to estimate heritability ($b = \frac{1}{2}h^2$). Part of the statistical analysis was done with the aid of the statistical packages SAS and MINITAB, available in the computing facilities of Cornell University.

Results and discussion

The vine type selection showed a significant effect (Figure 1). The length of the terminal leaflet is considered a reliable measure of the vine type (vine score-terminal leaflet length correlation: 0.76). If the response to selection is measured as a difference of the progeny of the selected parents and the base population, the results indicate a 28% of increase in the (V) group, 10% in the (VT) group and 3% in the (T) group for the length of the terminal leaflet, after one

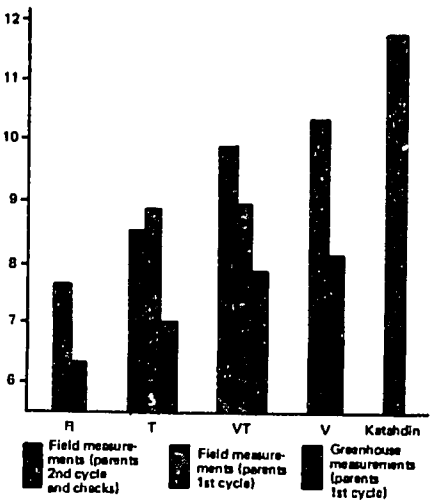

Figure 1. Effect of recurrent selection for vine and/or tuber characteristics on the length of the terminal leaflet.

cycle of selection. The difference of the (V) and (VT) groups with the (T) and (R) groups is significant ($p = 0.05$) considering both sets of parents (first and second cycle). The difference between the selected parents of both cycles within each group is not significant under field conditions. Greenhouse measurements showed a similar trend but a lesser leaf development was observed. Katahdin is not significantly different from the means of the (V) and (VT) groups, but it is significant with respect to the other two groups, a fact that provides a practical measure of the selection response.

Correlations among vine and tuber characteristics are shown (Tables 1, 2 and 3) for each subpopulation. The characters above described that are not shown in these tables yielded correlation coefficients not significantly different from zero for these comparisons. The relatively high correlations with characters of economic importance, such as yield, tuber size, general tuber appearance, give special interest to the selection for tuberosum-like vines.

Heritabilities for the (VT) and (T) groups are given for the vine characters. The estimates show a promissory future for the recurrent selection method in the improvement of vine type (Table 4). The data presented here provides the basis for a study of the correlated response for both groups of characters.

Table 1. Correlations among vine and tuber characters in the (V) group - (n = 265).

Vine characters	Tuber characters: Terminal leaflet Lenght (cm) Width (cm)	Distal lateral leaflet Length (cm) Width (cm)	Total dissection 2nd degree 3rd degree	General appearance 1/
Yield (g)	0.52 0.45	0.45 0.47	0.25 0.25 0.21	0.52
Number of tubers	0.17 NS	0.17 NS	NS NS NS	NS
Appearance 1/	0.40 0.45	0.34 0.42	0.15 0.14 0.11	0.50
Size 1/	0.35 0.38	0.28 0.32	0.12 0.15 NS	0.36
Uniformity 1/	0.19 0.19	0.16 0.15	NS NS NS	0.24
Depth of eyes	0.27 0.20	0.23 0.22	0.16 0.16 0.15	0.17
Secondary growth 2/	-0.18 -0.19	-0.14 -0.20	NS NS NS	-0.17
Unusual shape 1/	-0.14 -0.16	-0.12 -0.13	NS NS NS	-0.21

1/ These characters were measured using scores from 1 to 5.

2/ Presence or absence.

NS Correlation not significantly different from zero.

Table 2. Correlations among vine and tuber characters in the (T) group (n = 260).

Vine characters	Tuber characters: Terminal leaflet Length (cm) Width (cm)	Distal lateral leaflet Length (cm) Width (cm)	Total dissection 2n degree 3rd degree	General appearance 1/
Yield (g)	0.48 0.45	0.41 0.40	NS 0.18 0.18	0.54
Number of tubers	0.14 0.11	0.09 0.10	NS NS NS	0.09
Appearance 1/	0.31 0.30	0.25 0.24	0.16 0.14 0.10	0.32
Size 1/	0.40 0.38	0.37 0.36	0.21 0.22 0.16	0.47
Uniformity 1/	0.13 0.17	0.15 0.14	0.16 0.12 0.10	0.17
General shape 1/	NS NS	0.12 NS	NS 0.12 NS	NS

1/ These characters were measured using scores from 1 to 5.

NS Correlation not significantly different from zero.

Table 3. Correlations among vine and tuber characters in the (VT) group (n = 260).

Tuber characters	Vine characters: Terminal leaflet Length	Terminal leaflet Width	Distal lateral leaflet[1] Length	Distal lateral leaflet[1] Width	Total dissection 2nd degree	Total dissection 3rd degree	General appearance[1]
General appearance[1]	0.31	0.33	0.28	0.31	0.16	0.23	0.43
Size[1]	0.30	0.33	0.26	0.31	0.13	0.26	0.37
General shape[1]	0.19	0.17	0.17	0.20	0.15	0.18	0.16

[1] These characters were measured using scores from 1 to 5.

Table 4. Heritability of vine characters.

Selection group	Terminal leaflet Length	Terminal leaflet Width	Distal lateral leaflet Length	Distal lateral leaflet Width	General vine-score
VT	0.46±0.16	0.38±0.14	0.34±0.16	0.51±0.14	0.44±0.14
T	0.38±0.32	0.76±0.40	0.66±0.40	0.92±0.28	0.87±0.48

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LOW COST WARE POTATO STORAGE IN KENYA

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In Kenya potatoes worth US$ 9.8 million are commercially marketed yearly and 70% of that amount is retained for household consumption. Even the small farmers need to avoid low prices at harvest time through storage. With estimated storage losses of up to 20% (Durr et al., 1980) a demand for low cost, small-scale ware stores has developed.

Storage research in 1977/79 resulted in the development of a ware potato store, specifically designed for small scale farmers and based on natural ventilation (Homann et al., 1979). Based on historical price movements, use of these stores was reported profitable for periods of over three months. For shorter periods, storage in traditional houses seemed more attractive. Storage in farm houses was common and generally accepted. Simple improvements of house storage were likely to be adopted easily by farmers. In addition, the question arose as to whether the naturally ventilated store could be simplified since the chances of successful introduction and acceptance of any store type seemed likely to improve with increased simplicity of store design, associated with lower costs of construction and management.

With these objectives, a new series of storage experiments were undertaken jointly by the Kenya Ministry of Agriculture and CIP during 1979/81.

Materials and methods

Storage experiments were carried out at Molo, 2600 m. altitude in Kenya. Weekly mean minimum temperatures ranged from 8 to 14°C and weekly mean maximum temperatures from 16 to 27°C. Weekly mean relative humidity varied from 70-95%.

The following store types were compared:

1. Original design of naturally ventilated store (Homann et al., 1979), with flap controlled ventilation during cool night hours. Store capacity was approximately 2700 kg.
2. Simplified version of previous store of similar capacity with continuous unregulated ventilation. Tubers in this store were covered with 30 cm of straw.
3. African House 1 with a roof of corrugated iron and a ceiling of papyrus mat and walls of mud and gumpoles.
4. African House 2 with a thatched roof and no ceiling.

In African House 1 and 2 the following types of storage were compared:

- A 1.0 m^3 slatted box containing about 650 kg of potatoes.
- A heap of potatoes ventilated by means of a duct. Capacity approximately 1200 kg.
- A heap without a ventilation duct.

The sprout suppressant "Birgin" (I.P.C.) was applied as a dust (200 g/100 kg tubers) approximately 15 days after harvest as the tubers were placed in the stores. To enhance tuber absorption of the chemical all stores were sealed with plastic sheets for seven days after filling.

Storage periods ranged from 4-5 months. In all treatments the variety Roslin Eburu originating from the same field, was used.

Results and discussion

Table 1 shows storage weight losses in the various types of stores. Total weight losses varied from 7.8 to 11.6% and were mainly due to dehydration. Losses due to sprouting were generally higher in the heaps in the African Houses. This may reflect the difficulty in keeping these heaps sealed after application of the sprout suppressant.

Table 1. Effect of type of store on storage weight losses[1] after 5 month storage.

Store type	Type of weight loss (%): Sprouts	Reject	Dehydration	Total weight loss (%)
African house 1				
box	0.8	1.0	7.6	9.4
heap	3.0	0.7	4.6	8.3
ventilated heap	0.8	0.6	7.4	8.8
Mean	1.5	0.8	6.5	8.8
African house 2				
box	0.8	1.3	7.4	9.5
heap	1.6	0.4	7.7	9.7
ventilated heap	1.8	0.6	9.2	11.6
Mean	1.4	0.8	8.1	10.3
Natural ventilated store				
Original design	0.5	0.6	6.8	7.9
Simplified design	0.7	0.4	6.7	7.8
Mean	0.6	0.5	6.8	7.9

[1] Each figure is the average from two storage seasons.

In box storage, which is easily sealed, the use of sprout suppressant reduced storage losses considerably (Table 2). Additionally, non-treated tubers shrivelled resulting in loss of market quality. In further trials, I.P.C. (0.4% sprouting) was more effective as a sprout inhibitor than T.C.N.B. (4.2% sprouting) under these conditions.

Table 2. Effect of sprout suppressant (I.P.C.) on storage weight losses[1] after 4 month storage (cv Roslin Eburu) in African house.

Type of weight loss (%)	With sprout suppressant: house 1 %	house 2 %	Without sprout suppressant: house 1 %	house 2 %
Sprouts	0.6	0.4	5.8	6.5
Reject	0.8	1.8	0.7	0.4
Dehydration	7.9	5.8	8.4	8.6
Total	9.3	8.0	14.9	15.5
Mean total weight loss (%)	8.7		15.3	

[1] Weight loss (%).

There was little relation between store design and level of storage losses (Table 1). Under Molo conditions, management practices such as pre-storage selection of tubers and application of sprout inhibitor is likely to have a larger effect on storage results than specifics of store design. This is clearly demonstrated by the performance of the natural ventilated stores. The simplified design without control of ventilation performed equally well to the more sophisticated design ventilated with cool night air only. Also the difference between storage types within the African houses was small.

Under Molo conditions tubers can be stored effectively up to 5 months with limited weight losses when the sprout suppressant I.P.C. is used. The African house, with either thatched or corrugated iron roof, seems attractive for storing limited quantities of potatoes because of low cost and simplicity of design. Storage in boxes in these houses is possibly the most reliable way since tubers can be better protected from rodents, which sometimes created problems in unprotected heaps. Storage losses in slightly larger quantities may be kept low in the simplified naturally ventilated stores.

Use of the sprout suppressant Birgin (I.P.C.) was in these trials the single most important factor in reducing weight losses for storage periods of over 3 months. Efforts to limit ware storage losses at the small scale level should in the future possibly concentrate on this aspect rather than researching additional store designs.

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PROSPECTS OF LARGE SCALE PRODUCTION OF POTATO IN NIGERIA

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Introduction

Since the introduction of potatoes into Nigeria in the early 1940's (Staton, 1960), production has steadily risen from a mere 180 tonnes in 1940 to well over 50,000 tonnes in 1973 - 74 season with present estimates at 100,000 tonnes from an area of about 10,000 hectares (Ifenkwe, 1980).

The present demand for ware potato is estimated at about 1 million tonnes annually. The shortfall between demand and production accounts for the high prices of potato in Nigeria. Potatoes supplement other sources of carbohydrate such as yams, cassava, cocoyam, sweet potato and a host of other cereal crops such as millet, sorghum and maize. The latter are not sufficient to sustain the growing populations. Van der Zaag, (1976) reported that in most tropical and sub-tropical countries, the potato price expressed in terms of energy is 2 - 4 times higher than that to wheat or rice in the period of main supply of potatoes and 4 - 6 times in the period that potatoes have to be cold stored. It may therefore be worthwhile to question the rationale in a country like Nigeria with a host of other sources of carbohydrate embarking on large scale production of potatoes.

Potato could be incorporated into our farming system in those parts of the country where its growth can be sustained. The potato is by far superior to almost every other crop except the sweet potato in food production per hectare per day, (Horton, 1980). In Nigeria, up to two crops are possible in a year. In comparison to other tropical root crops such as yam and cassava which mature in 6 - 9 and 9 - 12 months respectively the potato matures in about 3 months and produces yields comparable to those of yams and cassava under good management (Table 1).

Because of its short growing cycle, the potato can be more easily incorporated into some cropping systems than other long cycle crops (Horton, 1980). Its ability to generate large amount of calories per unit of land and time promises well for intensifying agriculture in the tropics (Horton, 1980, Van der Zaag, 1976).

Table 1. Performance of some European potato varieties under Nigerian conditions.

Variety	Total yield t/ha[1/]		
	1979	1980	1981
Ajax	18.1	13.2	22.6
Mirka	15.9	15.6	22.4
Spunta	14.3	11.5	19.0
Nicola	18.3	17.5	17.9
Desiree (H)	13.0	15.6	22.2
Desiree (S)	--	--	21.0
*Maikarifi	8.7	9.8	--
Draga	9.3	12.9	--
Alpha	11.8	11.8	10.2
Estima	13.1	15.3	15.9
*BR63-5	11.6	12.4	--
Arka	16.0	15.4	17.8
Cardinal	13.7	13.9	20.1
Baraka	16.8	14.1	13.5
Jaerla	14.7	13.4	18.8
RC767-2	--	11.7	--
Roslin Ruaka	--	9.7	--
Rodosa	--	--	16.1
Maris Piper	--	--	18.4
Pentland Crown	--	--	16.3
Pentland Dell	--	--	15.7
Up-to-Date	--	--	24.2
*89488-5	--	--	16.4
*89435-10	--	--	18.9
*B9449-17	--	--	18.0
S.E. of Mean ±	1.9	1.24	0.97

* Local variety of local selections from crosses made outside the country or within the country

Desiree (H) = Dutch origin,
Desiree (S) = Scottish origin.

[1/] Total yields are those obtained during the rainy season period May-August.

Seed potato problem

Nigeria produces potatoes without importation of certified seed. Therefore, farmers are short of improved and healthy seed and have no alternative but to use remnants from the ware crop.

Prior to 1961, small quantities of fresh seed were imported from the U.K. for direct distribution. As demand increased, an unsuccessful attempt for local seed multiplication collapsed because due to insufficient seed storage facilities and continuous cropping in the same area and bacterial wilt increase. The National Seed Service is still unable to include the potato in its scheme possibly because potato is difficult to preserve.

Disease problems

In Nigeria the bacterial wilt and the late blight are the most serious disease problems. Together they can result in total crop failure. The late blight disease can be controlled by fungicides. Bacterial wilt is wide spread in the potato growing areas and is increased by cultivation of crops (Erinle, 1976) such as tomato and egg plant in the same area. Information on control is scanty. Harris (1976a) reports that bacterial wilt is confined to tropics, sub-tropics and warm temperate regions. It is more serious in the lower altitudes and above 2,100 meters (Harris, 1972, 1976b). In Nigeria potato is presently grown 1,200 - 1,500 meters above sea level. Soil temperature at the wilt "ceiling" is around 15°C (Harris, 1972) corresponding with the lower temperature limit for growth in culture. Using this parameter and the elevation effect, they were able to demarcate areas in Kenya for seed potato production. Similarly areas in Nigeria such as the Mabilla Plateau which exceeds 1500 meters elevation might be used for seed potato production. Because of our limited facilities, most of the breeding for resistance to bacterial wilt disease has been done outside the country notably at the University of Wisconsin-Madison and true seed segregating for various characters is sent to the National Root Crops Research Institute's Potato Programme in Jos for observation and selection. Seed tubers have been received through CIP regional headquarters in Nairobi for screening against bacterial wilt resistance. Significant progress has not yet resulted in the identification of wilt resistant lines with late blight resistance, high yield and desirable tuber quality. Although it has not been possible to identify any single line with total immunity some lines received from USDA Beltsville in 1977 (Table 2) have maintained reasonable tolerance to the disease such as clones, B9488-8, B9488-5, B9494-3, B9466-5 and B9449-17.

Also some lines from CIP such as Y-66-20-40 CIP 573275, CIP 720088 and CIP 720084 have shown promise of wilt resistance and high yield. Varieties with high levels of resistance at a given location may not survive in another geographic area because of specific strains of the pathogen or because resistance is not expressed under certain environmental conditions. It is not therefore surprising that we are achieving very little result from some of the material bred outside the country.

Results of 1979 and 1980 (Table 3) indicate that disease incidence increased with increasing planting depth and was reduced

by planting on flats though not significantly. Two to three ploughings during the dry season considerably reduced incidence of bacterial wilt on both flat and ridges.

Preliminary results (Anonymus, 1980) suggest incidence and severity of bacterial wilt is reduced by grass mulch and that earthing up the soil in the absence of mulch increases the bacterial wilt incidence.

Table 2. Assessment of advanced clones for bacterial wilt resistance.

Acq. N°	% Wilted stand		Potential total yield (t/ha)	
	1979	1981	1979	1981
B9450-7	5.0	9.2	22.2	12.6
B9449-10	0.0	23.4	21.5	14.1
B9477-2	7.5	2.6	21.3	10.6
B9488-8*	5.0	4.3	21.2	29.7
B9488-5*	0.0	4.2	20.6	15.4
B9435-10	0.0	7.5	20.3	14.9
B9462-1	7.5	11.7	20.3	11.3
B9466-3	5.0	10.9	20.3	20.0
B9494-3*	0.0	0.9	20.2	26.0
B9466-5*	0.0	1.7	18.3	17.1
B9449-17*	0.0	3.4	16.8	11.6
B9494-2	20.0	10.9	16.0	18.8
B9466-7	2.5	4.3	15.7	12.6
B9435-2	8.0	3.4	15.3	10.5
B9449-16	25.0	9.2	13.9	15.7
B9449-20	0.0	9.2	13.8	14.1
B9450-1	37.5	17.8	--	12.1

* % of wilted stands were taken out of 120 stands in each year.

Table 3. Effect of planting depth and cultivation method on the incidence of bacterial wilt (mean number of wilted stands).

a. One ploughing at time of planting:

	Depth of planting 1/			Mean
	6 cm	10 cm	14 cm	
Ridge 2/	13.2	16.3	16.5	15.3
Flat 2/	12.0	14.5	13.3	13.3
Mean	12.6	15.4	14.9	3/

1/ Standard error of depth of planting (D) = ± 1.8

2/ Standard error of method of planting (M) = ± 1.5

3/ Standard error of interaction D x M = ± 2.5

b. Three ploughings before planting:

	Depth of planting 1/			Mean
	6 cm	10 cm	14 cm	
Ridge 2/	1.2	2.5	1.7	1.80
Flat 2/	3.3	2.7	2.2	2.7
Mean	2.3	2.6	2.0	3/

1/ = ± 1.0

2/ = ± 0.52

3/ = ± 0.63

Mechanization problems

Further increases in potato hectrages will probably increase through mechanization.

Machines for pre-harvest operations probably will be useful because rainfall is minimal. However problems may be encountered in harvest operations because often the peak of rainfall coincides with the peak of harvest (mid July to mid August). In some years harvest must be delayed for more than two weeks during which many tubers rot in the soil (Table 4).

A possible solution may be to commence planting at least one month before the onset of rains and to use irrigation to provide water to the potato crop at the early stages of growth.

Table 4. Average total monthly rainfall at Jos (1981) and Vom (1978 - 1981) Nigeria in mm.

	Monthly rainfall		Days with 5 mm or more rain
	Jos mm	Vom mm	Vom
January	2.0	0	0
February	2.3	0	0
March	24.1	16.8	0.3
April	94.7	66.8	3.0
May	190.5	147.3	10.0
June	228.1	165.3	9.3
July	323.9	291.0	14.5
August	281.4	304.3	16.5
September	208.5	185.0	10.3
October	42.7	55.8	2.8
November	3.1	4.4	0.2
December	1.5	0	0

Harvesting and Storage Problems

The major constraint affecting increased production in Nigeria, is absence of suitable storage houses for seed and ware potatoes. In most of the traditional potato growing areas, the minimum temperature very rarely goes below 10°C. Worse still is the large fluctuation between day and night temperatures. It is difficult to control sprouting and consequently to extend the storage period. Under room temperature most varieties will hold for up to 1 - 2 months but when stored in thatched houses with good ventilation the period could be extended for a month or two more depending on variety. Cold rooms would have to be considered for large scale production of seed. The use of cool outside air which is now gaining popularity in some high altitude tropical countries as in Kenya and the use of diffused light as in the Philippines are being tried. However, night temperatures are not sufficiently low for most of the storage period. Preliminary results indicate that these methods though not very effective at the moment could enable storage up to 3 - 4 months.

It is pertinent to mention, that cold storage will not eliminate losses due to diseases which are carried over from the field. Crop hygiene must be emphasized and only those tubers which are free from disease defects should be stored.

Conclusions

Although Nigeria's weather conditions place it on the marginal potato producing part of the world and yields might not be expected to be as high as the traditional potato producing areas, the potato can play a significant part in boosting the agricultural production of the country in the year 2000.

Although also many production problems have been highlighted, these are not insurmountable in view of the very important role Nigeria attaches to food sufficiency. Traditional peasant farmers have in spite of the many problems continued to grow potatoes for the past fifty years or more without the use of improved seed or adequate husbandry practices. It is therefore hoped that the effort of CIP and the other National Research Organizations will in the near future provide answers to help these small scale farmers who form the bulk of our farming population. Development of the many irrigation schemes in the traditional potato producing areas of Nigeria will no doubt lead to a rapid transformation of our capacity to produce potato to supplement other root crops.

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MANIPULATION AND CONTROL OF SEED TUBER BEHAVIOR

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The major emphasis of potato seed certification programs and improvement of production in developing countries has been on elimination of debilitating diseases such as viruses. The emphasis has been properly placed, because diseases are a major hinderance to economic yields in many areas. However, in the more technologically advanced countries where diseases are controlled and as production gets more sophisticated in the developing countries, we should also be looking at the physiological condition of seed in relation to productivity. This means control of physiological age of seed which influences plant vigor, numbers of stems arising from a seed piece, number and time of tuber set, relative maturity of the plant and, finally, size, and yield at harvest. In this day of advanced technology, we should be able to grow economic yields of potatoes in normally alien environments such as hot climates. By the year 2000, we will have control of these processes and be able to manipulate growtn behavior of the plant and tubers to economic advantage.

As we gain greater knowledge of the mechanism or mechanisms involved in controlling tuberization and enlargement, then steps can be taken to alter the balance in favor of tuberization if this is desired. This can be done in a number of possible ways, which generally will have to be worked out for a particular location and cultivar. It is important to know the physiological status or condition of seed, whether it is locally grown or imported, so that necessary steps can be taken to obtain a desired behavior. At the present time, we do not have any criteria, physiological or otherwise, to identify physiological status or age. By the year 2000, growers will be able to identify physiological age of seed by simple means and take appropriate steps to manipulate the behavior of desired goals. Manipulation of seed behavior can be obtained through: treatment of seed with growth regulators (Burton, 1966; Holmes et al., 1977; Madec and Perennec, 1969); through altering time of planting for a more favorable environment (Harris, 1978; Iritani, 1981; Ivins and Milthorpe, 1963); through cutting or other physical alteration of the seed (Burton, 1966; Ivins and Milthorpe, 1963); through presprouting, desprouting, warming of seed, exposure to light and high temperatures (Allen et al., 1980; Burton, 1966; Cutter, 1978; Harris, 1978; Iritani, 1981; Ivins and Milthorpe, 1963; Van Der Zaag, 1973); and through alteration of the external environment in terms of fertilizer and moisture level (Burton, 1966; Harris, 1978; Ivins and Milthorpe, 1963).

Equally as important as controlling the overall behavior of seed potatoes is to be able to control variability in behavior withing a particular lot of seed (Iritani, 1981).

From a genetic point of view, the potato is inherently quite variable or heterozygous. Physiologically, one tuber can also be quite different from another due to differences in time of tuber initiation, amount of starch incorporated and rate of tuber enlargement. Greater uniformity in behavior will be achieved in the future with use of growth regulators which would induce more uniformity of set and enlargement.

In a paper presented at the NATO Advanced Study Institute on Plant Regulation and Work Agriculture, J.C. Hugill (1978) of the World Sugar Research Organization stated that "The development and application of growth regulators may be the most important strategy for the future of world agriculture and sustaining of the human race." There are many possibilities for the use of growth regulators for controlling the growth and physiological behavior of potatoes (El-Antalty et al., 1967; Gifford and Moorby, 1967; Goodwin, 1967; Hardy, 1978; Hartmans and van Es, 1979; Holmes et al., 1970; Humphries, 1958; Krug, 1963; Madec and Perennec, 1969; Sachs and Thimann, 1964; Scott, 1978; Takashima et al., 1962). Seed tubers could be treated to break dormancy, regulate apical dominance, and promote plant vigor. Foliar applications of growth regulators could be made to promote or limit vegetative growth, promote carbohydrate movement into tubers, delay senescence, increase LAD (leaf area duration), and regulate tuberization.

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STUDIES ON THE ROOT SYSTEM IN POTATO PLANTS

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Detailed and numerous studies on the aerial parts of potato plants have been made to clarify their productivity, but the role of the root system in growth has remained far from clear. In 1975 we started systematic investigation of root growth and morphology under field conditions. The following paragraphs summarize the results of some of these studies. (Iwama, 1981, Iwama et al., 1981).

The root system showed large differences among varieties and between locations. Figure 1 presents an example with four varieties at two locations. Root dry weight (DW) was the largest in Norin No. 1 of late maturity, followed by Shiretoko of late maturity and Danshakuimo of early maturity, and the smallest in Priekulshiirannii of very early maturity. In each variety it was larger at Sapporo in alluvial clay loam soil than at Shimamatsu in volcanic ash sandy loam soil. Although leaf area index (LAI) also showed varietal and locational differences and there was a highly significant correlation between maximum root DW and maximum LAI during the growing season (r=0.95**), these differences in root DW appeared at an earlier stage of plant growth than for those with leaf area. In addition, as shown in Figure 2, the tuber yield increased proportionally to the increase of root dry weight duration (RD) during the period from the initial flowering stage to the leaf yellowing stage, where RD was cal-

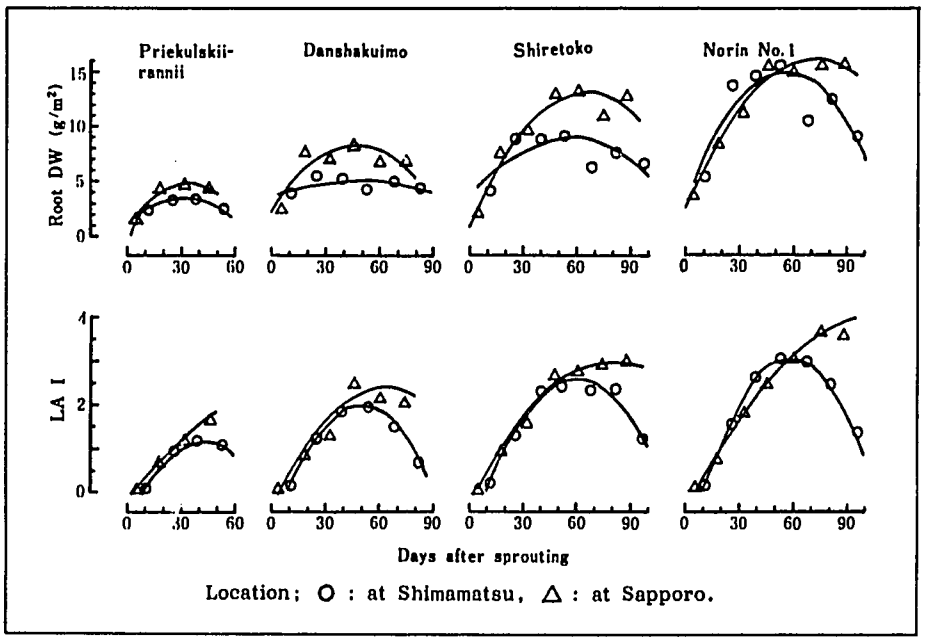
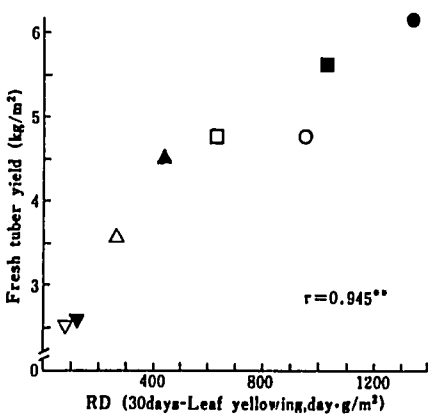


Figure 1. Changes in root dry weight and LAI (leaf area index) during the growing season.

culated from the quadratic regression equation of root growth (Figure 1), because larger root DW delayed leaf senescence and thus prolonged the tuber bulking period. These results suggest that procedures for increasing root DW, whether by means of breeding or cultivation, will result in a higher tuber yield accompanying a longer growing period.



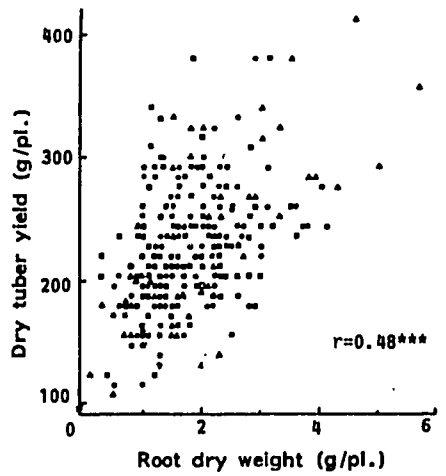
Location; Open symbols: at Shimamatsu
Closed symbols: at Sapporo.
Variety; ▽ : Priekulskii-rannii,
△ : Danshakuimo,
□ : Shiretoko,
○ : Norin No. 1.

Figure 2. Relationship between root dry weight duration (RD) and fresh tuber yield.

A large variation in root DW was also found when 268 unselected clones derived from six crosses were observed. Root DW ranged from 0.09 g/pl to 5.68 g/pl at the maximum stage of top DW (the top max. stage), which related significantly with stem DW (r=0.80***), leaf DW (r=0.68***), and the tuber yield (Figure 3). Since a significant correlation was also found between root DW and growing period (r=0.48***), the hybrid clones were divided into six maturity groups to consider the relations of root DW with other characters in two aspects: i.e. between the clones of different maturity and within the clones of same maturity.

In the comparison of the characters among different maturity groups, mean root DW among the same maturity clones increased proportionally with the increase of mean growing period (r=0.99***). Since the differences of mean leaf DW among maturity groups were smaller than those of root DW, the mean ratio of root DW to leaf DW was also higher in the later group. In addition, since mean tuber yield increased with the increase of mean growing period, a highly positive correlation of root DW with the tuber yield in the hybrid population (Figure 3) is partly due to the relations of these characters with the growing period.

Regarding the relations between the characters with the clones of the same maturity, the differences of tuber yield among clones in the earlier maturity group strictly related to those of root DW and leaf DW. It indicates that larger root DW as well as leaf DW is essential to achieve a higher tuber yield among clones of earlier maturity. On the other hand, in the later maturity group the differences of the tuber yield among clones seemed to be rather independent from those of root DW and leaf DW, and thus might be dependent on those of dry matter production per unit root DW and also per unit leaf DW.



Maturity group (Days from sprouting to leaf yellowing);
△: 68 - 80, □: 81 - 90,
○: 91 - 100, ●: 101 - 110,
■: 111 - 120, ▲: 121 - 145.

Figure 3. Relationship between root dry weight and dry tuber yield in the hybrid population.

In addition, we analyzed the transmittance of the parental characteristics to the hybrid clones based on the data of 268 hybrid clones (Table 1 and Table 2). Of the male parents, A and B were the early maturity breeding materials and C was the late one. Root DW and tuber yield were largest in C, followed by B and smallest in A. On the other hand, tuber DW at the top max. stage was smallest in C, and leaf DW did not show significant differences between male parents. The female parents, Danshakuimo (D) and Toyoshiro (T), were early maturity varieties. D tended to have larger root DW and leaf DW than T,

Table 1. Comparisons of the characters among the hybrid populations with different male parents.

Variable	Population 1/						Significance 2/		
	AM		BM		CM		AM:BM	AM:CM	BM:CM
	Mean	SD	Mean	SD	Mean	SD			
The top max. stage									
Root DW 3/	1.65	0.80	1.76	0.73	2.05	0.98	NS	**	*
Leaf DW	20.85	8.21	21.60	7.73	21.33	7.69	NS	NS	NS
Roof/Leaf (x100)	8.1	3.0	8.3	2.8	10.3	6.8	NS	**	*
Tuber DW	106.74	38.76	97.85	37.59	85.80	32.64	NS	***	*
The harvesting stage									
Growing period (days)	90.3	12.5	89.2	9.7	111.3	17.1	NS	***	***
Tuber DW yield	216.3	49.5	218.5	39.1	249.1	59.9	NS	***	***

1/ AM: DxA and TxA, BM: DxB and TxB, CM: DxC and TxC.
2/ *, **, and *** show significant differences at 5, 1 and 0.1%, level respectively.
3/ DW = dry weight (g/plant).

Table 2. Comparisons of the characters among hybrid populations with different female parents.

Variable	Population[1/]				Significance
	DF		TF		
	Mean	SD	Mean	SD	
The top max. stage					
Root DW [2/]	1.99	0.81	1.64	0.89	***
Leaf DW	23.21	7.99	18.98	7.09	***
Tuber DW	87.14	31.52	107.18	40.35	***
The harvesting stage					
Growing period (days)	97.9	17.3	97.5	17.2	NS
Dry tuber yield	227.3	46.8	231.1	59.8	NS
Tuber DW yield/Root DW	131.5	63.5	184.2	144.5	***
Tuber DW yield/Leaf DW	11.2	5.3	14.2	9.4	***

1/ DF: DxA, DxB and DxC; TF: TxA, TxB and TxC. Symbols are the same as those shown in Table 1.

2/ DW = dry weight (g/plant).

although tuber yield did not show a significant difference between the female parents.

Table 1 shows that the population from the crosses with C male parents had the wider range of variations and significantly larger values in root DW, growing period, and tuber yield than those with A and B male parents. It indicates that larger root DW resulting in a higher tuber yield would be obtained more effectively from the populations derived from the crosses with the late maturity parent than from those with the early ones. On the other hand, Table 2 showed that the population from the crosses with T female parent had smaller root DW and leaf DW than the population from D as female parent. The growing period and tuber yield did not show any differences among these populations, so that the ratios of tuber yield to root DW and leaf DW were significantly higher in the population from the crosses with T as female parent. It indicates that a higher ratio of tuber yield to root DW might also be effected, using Toyoshiro derived from the backcrosses population of S. tuberosum to wild race.

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CHEMICAL INDUCTION OF APOSPOROUS APOMICTIC SEED PRODUCTION

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Summary

This paper proposes forming clonal true seed through apospory and chemical induction of autonomous seed development. This is in contrast to the apomeiotic diplospory breeding approach. The clonal true seeds have great potentials for uniform seedlings from TPS, easy erradication of viruses from infected clones, mutation breeding, and clonal maintenance, and distribution of potato germ plasm in the form of true seed.

Introduction

Hermsen (1980) proposed a "breeding approach" for achieving apomixis in potato varieties to obtain genetically uniform seedlings for successful utilization of true seed for potato production. Obtaining apomeiotic diplospory was proposed by combining complete asynapsis and restitution nucleus formation. It was also proposed to mutagenically induce genes for autonomous development of the apomeiotically produced gametophyte into seed. Then, the two steps can be integrated into potato varieties through breeding.

Proposal - chemical induction of aposporous seeds

The present proposal, which may revolutionize potato production and research if successful, is in line with Hermsen's use of apomixis. It includes, however, two different components for obtaining apomictic seeds in comparison to Hermsen's scheme. It proposes apospory instead of apomeiotic diplospory and chemical induction of autonomous seed development instead of the "breeding approach." Clonal true seeds produced by the present method can be utilized not only for obtaining genetically uniform seedlings for use of true seed for potato production, but also for three other purposes as will be discussed later.

Production of genetically unreduced eggs by apospory

The first step to get clonal true seeds is to produce genetically unreduced eggs. Apospory has several advantages over apomeiotic diplospory for obtaining genetically unreduced eggs. First, cytological studies to confirm apospory are much simpler than those of apomeiotic diplospory. Second, apospory results in production of unreduced gametophytes more stably than apomeiotic diplospory. Expression and degree of asynapsis are not stable and may vary between meiocytes, plants and environments (Beadle, 1933; Li et al., 1945). Moreover, restitution nuclei may leave one or more chromosomes outside the nucleus and, thus, create undesirable aneuploids. Third, apospory in potatoes was recently demonstrated by Iwanaga and Peloquin (1982). They cytologically studied early stages of aposporous development which were found to be very similar to those reported as the Hieracium pilosella type of stable apospory reported by Gustafsson (1939). Thus, the expectation of using apospory proposed here has a good base.

It seems that at least some potato clones, but possibly not all, have the genetic potential of apospory (Iwanaga, 1980). Thus, it may be necessary to externally enhance aposporous development. A systematic study to chemically induce apospory is necessary.

There are some reports on chemical modification of normal embryogenesis. Yasuda (1940) injected aqueous solutions of Belvitan into the ovaries of Petunia violacea. In some cases the nucellus cells were enlarged as the result of such stimulation; in others, the egg had divided once or twice, forming a small proembryo; and in others, the antipodal cells had increased in volume. Van Overbeek et al. (1941) injected several chemical substances into the ovary of Datura stramonium in an unsuccessful attempt to stimulate parthenogenetic development of the egg cell, but instead several multicellular warty outgrowths filled the embryo sacs. The shape and contents of the cells closely resembled those of the integumentary tapetum and they also showed the diploid number of chromosomes. Fagerlind (1946) treated some of the pistils of Hosta with 1 percent heteroauxin in lanolin and the controls with pure lanolin; the latter dried up within four or five days. Auxin-treated pistils, on the other hand, continued to remain attached to the plant and three weeks later contained young adventive embryos. These experiments clearly indicated the possibility of chemical modification of embryogenesis.

Chemical induction of autonomous seed development

Normal development of endosperm which is initiated by triple fusion is regarded as essential for viable seed production. The question is how to stimulate the central cell to develop into endosperm without fertilization. Thus, Hermsen (1980) proposed mutagenetically inducing genes that stimulate autonomous endosperm development from an unfertilized central nucleus. Alternatively, chemical application on flowers for the development is proposed here. Chemical induction of apomixis could be a more promising approach than the breeding approach since it would not be as dependent on genotype. Once an effective method to induce apomictic seed development is found, it can be utilized for other existing clones. One of the most difficult problems of the breeding approach is to combine all necessary genes in a good genotype.

Apomictic seed formation was induced in potatoes by spraying emasculated flowers with several concentrations of 2, 4-D (Irikura, 1981a). Two of four 4x cultivars and three of six 2x clones produced apomictic seeds with 2n chromosomes. Seedlings were apparently similar to their parents, although phenotypic identity

could not be established with certainty (Irikura, 1981b). Application at flowering time did not directly induce 2n egg formation (apospory or diplospory), but may have induced parthenogenetic egg development.

Induction of autonomous seed development is possible in some species. In some varieties of fig, the formation and development of apomictic embryos and viable seeds without fertilization were obtained by treating the flowers of the fig with a mixture of vitamins and amides of NAA (Arendt, 1970). While studying the large ovaries in the maize line KZR-136-1-R (a total of 668 embryos sacs were examined from 72 plants), 45 embryo sacs were observed in which endosperm developed without fertilization (Laikova, 1970). Possibly the polar nuclei in the embryo sacs of the large ovaries fused without fertilization and initiated apomictic endosperm. Elevated ploidy levels enhanced development of the unfertilized egg cell of Poa palastris into the embryo without fertilization (Zhirov, 1970). In this way, chemicals, genotypes, or ploidy levels may induce autonomous seed development.

Potentials of aposporous apomixis

Chemical induction of aposporous apomictic seed has great potential for potato research and production. This assures genetic uniformity in seedling families. Second, breeders and foundation seed programs may be able to use aposporous seed to eradicate virus from infected clones without going through time-consuming stem-tip culture procedures. Thus, the use of apospory will be especially useful for developing countries without established foundation tuber-seed programs to produce genetically uniform seedlings for the use of true potato seeds. Third, clonal true seeds produced by apospory can be used for mutation breeding just as are other self-pollinated, seed-propagated crops, thus avoiding inherent problems of applying mutagens on vegetative tissues (Brown, 1982). Finally, maintenance and distribution of potato clones can be done by true seeds. Clonal maintenance of potatoes is by planting tubers every year, which is laborious and expensive. Further, loss of germ plasm can occur due to human mistakes, killing frost, hail storm, storage problems, and degeneration by virus infection. Distribution of germ plasm in the form of tubers has been restricted due to bulkiness, perishability and quarantine problems. The use of aposporous seeds could solve the problems.

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AN EFFICIENT METHOD FOR SCREENING LARGE NUMBERS OF POTATO SEEDLINGS FOR RESISTANCE TO MELOIDOGYNE SPECIES

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Summary

Due to limited availability of space and need for testing a large number of genotypes developed in a breeding program, a method for a rapid and efficient seedling screening was developed. Use of 50 cc plastic cups and a proper soil mixture was tested. Seedlings were inoculated with 4,000 Meloidogyne incognita eggs 2 weeks after transplanting them in plastic cups. Fourty-five days later plants were removed from soil and roots were examined for nematode infection. This method provides an efficient and rapid seedling screening procedure for testing a large number of genotypes in a limited available space.

Introduction

Space is a major limiting factor in screening a large population of clones or breeding lines for resistance to Meloidogyne species. In a breeding program when several sources of resistance are used usually a large number of families and genotypes is developed. In a proper screening program an average of 50 to 100 genotypes per family need to be tested. It is important to test those genotypes during the same period of time when the temperature and environmental conditions favor parasitic activities of Meloidogyne species. An effective screening method was needed to test a large population of genotypes using limited available space.

Results and discussion

Feasibility of using small 4-oz plastic cups to grow small seddlings for testing was investigated. Initially a large number of seedlings were transferred to these cups containing normal potting soil. However, the majority of the seedlings did not grow well and died prematurely. To determine the effect of soiltype on the growth of seedling in these cups, a variety of soil mixtures were used in an experiment. Young seedlings were transplanted in plastic cups containing different soil mixtures. A 3:2 Pomacocha soil from Huancayo, Peru: sand mixture (a potting soil previously used in nematology program) was used as check soiltype. Two weeks after transplanting, seedlings were inoculated with 5000 Meloidogyne incognita eggs. Two months later plants were removed from soil, roots were examined for nematode infection and plant height, fresh top and root weights were recorded. There were no differences in the intensity of nematode infection among treatments. However, there were significant differences of plant height, fresh top and root weight among treatments. Plant growth in some soil mixtures was significantly better than that grown in the check soil (Figure 1). The soil mixture of 2:2:1 jiffy mix: sand: Pomacocha soil was the best medium for seedling test. This method provides an efficient and rapid

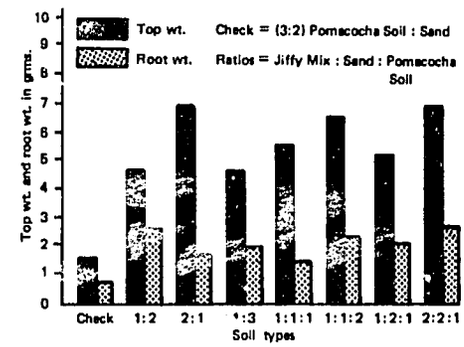

Figure 1. Growth of potato seedlings in different soiltypes.

seedling screening procedure for a large number of genotypes tested for resistance of both root-knot and potato cyst nematodes (Figure 2). Evaluation of susceptible seedlings is further facilitated by pulling out the soil and roots from the cups and recording the root galling directly (Figure 3). Since most of the root system is found in the outer part of the soil and in contact with the inner portion of the plastic cup, the need for washing the root system for evaluation is reduced. Finally, since early maturity and adapt-

Figure 2. Mass screening of potato seedlings for resistance to nematodes.

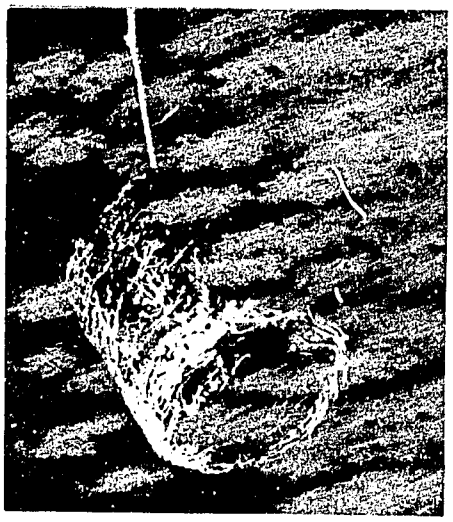

Figure 3. Direct examination of the root ball for nematode infection.

ability to warm temperature is incorporated with resistance to Meloidogyne and Pseudomonas solanacearum, a large segment of the population tested will produce tubers. Therefore, additional data can be obtained on the resistance or susceptibility of tubers to Meloidogyne infection (Figure 4).

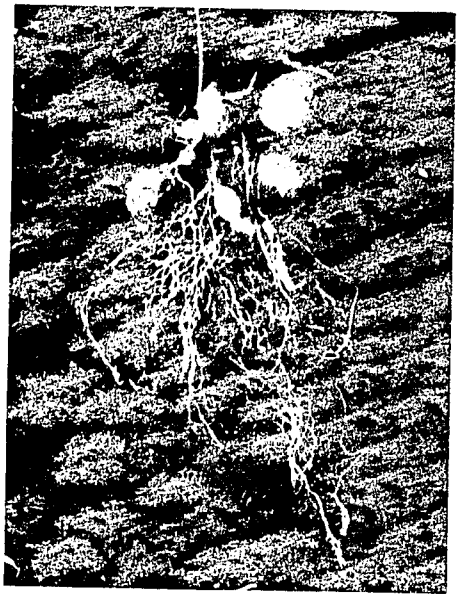

Figure 4. Tuber and root infection of seedlings tested for resistance to Meloidogyne incognita.

RELATIONSHIPS OF RESISTANCE TO MELOIDOGYNE INCOGNITA AND PSEUDOMONAS SOLANACEARUM IN POTATOES

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Summary

A large segment of a breeding population with a high percentage of Meloidogyne resistant segregating progenies is resistant to at least one population or race of Pseudomonas solanacearum. Families with high percent segregating progenies resistant to M. incognita had also a high percent resistance to 4 strains of P. solanacearum. Results indicate that it is simpler to screen for resistance to M. incognita and then the selected material be tested for resistance to P. solanacearum.

Introduction

Interrelationships of Meloidogyne incognita and Pseudomonas solanacearum on potatoes has been established by Jatala et al. (see References). Jatala et al. (1975) described a synergetic relationship between these two organisms. Wilting of potatoes due to P. solanacearum increased in the presence of M. incognita both under greenhouse and field conditions. Since these two pathogens have similar ecological distribution and often occur together, effort has been concentrated in combining the resistance of these organisms. Results indicate that plants initially selected for resistance to M. incognita also had resistance to certain strains of P. solanacearum. Present study was initiated to determine the relationships of dual resistance in several families of the crosses consisting of M. incognita resistant parents.

Results and discussion

Seedlings of eleven families of the first and second cycle of recurrent selection segregating up to 60% for resistance to the peruvian Meloidogyne incognita population race 3 were tested for resistance to 4 strains of Pseudomonas solanacearum. Seed were germinated in a mixture of sand and peat moss in flats. After 35 days plants were inoculated with 500 ml (2 x 10 cells/ml H_2O) bacterial suspension of P. solanacearum strain 013 race 3. Plants were allowed to grow in greenhouse at a temperature range of 26° - 31°C. Wilting was recorded and the susceptible plants were discarded. Stem cuttings of resistant plants were rooted in sand and transplanted into 15 x 15 cm clay pots. After 20 days plants were individually inoculated with P. solanacearum strain 048 race 3, 003 race 1, and 052 race 1.

All the resistant plants were retested for confirmation of resistance to strain 013 race 3 of P. solanacearum. A large segment of this population was resistant to at least 1 population or race of P. solanacearum. However, number of resistant plants to the 4 strains of P. solanacearum varied from 0 to 31 plants per family (Table 1). This percent of resistance was directly correlated with the percent segregation for resistance to M. incognita. Families with the highest percent of segregating progenies resistant to M. incognita had also a higher percent resistance to 4 strains of P. solanacearum. Results confirm the previous findings that it is simpler to screen for resistance to M. incognita and then the selected material be tested for resistance to P. solanacearum.

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Table 1. Correlation of resistance in some diploid clones of the first and third cycle of recurrent selections to Meloidogyne incognita and Pseudomonas solanacearum.

Clone	Plants resistant to M. incognita No.	Plants resistant to P. solanacearum* No.
MBN 1	5	1
MBN 2	15	6
MBN 3	24	3
MBN 4	27	31
MBN 5	22	9
MBN 6	0	2
MBN 7	3	0
MBN 8	27	6
MBN 9	13	13
MBN 10	61	7
MBN 11	1	5

* Resistant to 4 - 5 strains of P. solanacearum.

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PROMISING CONTROL MEASURES FOR ELIMINATION OR PROTECTION OF DEVELOPMENT TUBERS FROM ROOT-KNOT NEMATODES

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Summary

Oxamyl, phenamiphos and thionazin were most effective among several nematicide dips used to eliminate Meloidogyne chitwoodi from seed pieces in greenhouse trials. Similar treatments also were most effective in protecting developing tubers from M. hapla invasion. Seventeen other materials reported to be nematicidal were less effective or extremely phytotoxic.

Introduction

Root-knot nematodes are widely distributed in localized land areas used to produce the world's potato crop. Yet there still remains vast areas that are not contaminated, treated areas that have been decontaminated and areas with minor populations below threshold levels that should be protected from further dissemination. Control of root-knot nematodes where high populations now exist also improve quality and quantity. Elimination of these pests in seed pieces and protection of developing tubers with chemical seed piece treatments are viable control alternatives (see 5 references cited) until other measures e.g. biological control agents or resistant varieties are available. A study was initiated to investigate effectiveness of seed piece treatments as a control alternative.

Results and discussion

Trials established in 1981 consisted of emersing potato seed pieces (Solanum tuberosum cv. Russet) in 10 minute soaks in solutions containing various concentrations of chemicals. Some seed pieces were naturally infected with Meloidogyne chitwoodi and others were nematode-free. Acetone was used frequently as a carrier at 50% by volume of the soak solution. After treatment seed pieces were surface-dried, dusted with five percent captan and planted (one seed piece per gallon can) in sandy loam. During the first week after planting, containers with nematode-free seed pieces were inoculated with a suspension containing 500 M. hapla larvae. Treatments in experiment one were replicated ten times. Root-samples were examined for galls at post harvest. Tubers were harvested approximately 120 days after shoot emergence, stored 30-45 days at 5°C and then peeled to detect nematodes. In another experiment, M. incognita infected tubers were soaked for different time periods in various concentrations of oxamyl and phenamphos. Parallel to chemical dips, infected tubers were soaked in hot water (45° and 60°C) for different time periods to determine the efficiency of these methods for controlling nematodes. Tubers were planted in clay pots after 15 days and plants were allowed to grow in a screenhouse. After 50 days roots were carefully removed from soil by washing and rated for nematode infection.

Oxamyl, phenamiphos and thionazin were the most effective materials used in these trials. Oxamyl, a carbamate with short-term protection, was effective in preventing post-planting infection of M. hapla at all rates tested (Table 1). Similar treatments also eliminated the source of M. chitwoodi from infected tubers except the highest rate where contamination from other treatments may have occurred. M. incognita was controlled effectively in high concentration of oxamyl (Tables 2 and 3).

Phenamiphos usually eliminated the three nematode species (Tables 1, 2 and 3). However, some infection was found in one of the highest rates for M. hapla and M. chitwoodi. Some problems with phytotoxicity had occurred at higher rates in preliminary trials not included in this report. Apparently phytotoxicity varies with stage of dormancy, variety and perhaps post planting conditions. This material offers long term protection of at least seven months (according to the label) and may be an ideal control material. Of the remaining materials included in the first experiment (Table 1) only thionazin treatment resulted in excellent control. Unfortunately the instabile formulation of this organo-phosphate has resulted in the withdrawal of this material from the U.S.A. market.

Screening of 16 additional materials against M. chitwoodi in contaminated tubers has not identified other effective treatments except carbofuran.

Table 1. Efficiency[1/] of various nematicides on root-knot nematodes for protection of the subsequent tuber generation or as erradicant for Meloidogyne in infected seed pieces.

Treatment [2/]	Meloidogyne hapla		Meloidogyne chitwoodi	
	Infection [3/]	Plants missing	Infection [3/]	Plants missing
Oxamyl 24%	0/8	2	5/5	0
Oxamyl 12%	0/9	1	0/10	0
Oxamyl 6%	0/9	1	0/10	0
Oxamyl 3%	0/10	0	0/9	1
Phenamiphos 4.5%	2/3	7	0/5	5
Phenamiphos 3.5%	0/9	1	0/10	0
Phenamiphos 2.5%	0/10	0	0/9	0
Phenamiphos 1.5%	0/10	0	0/10	0
Phenamiphos 0.5%	0/7	3	0/10	0
Oxamyl 12% + acetone	0/9	1	0/10	0
Phenamiphos 3.5% + acetone	2/7	3	0/5	5
Phenamiphos 2.5% + acetone	0/10	0	0/9	1
Phenamiphos 1.5% + acetone	0/10	0	0/7	3
Sodium Olinate 10^{-2} + acetone	0/7	3	6/9	1
Butyric acid 10^{-8} + acetone	0/5	0	6/9	1
Phenol 5% + acetone	8/8	2	1/9	0
Thionazin 11% + acetone	1/8	2	0/8	2
Control H_2O + acetone	3/8	2	4/9	1
Control H_2O	4/10	0	6/10	0

1/ Chi square comparisons. Significance P 0.05.

2/ 10 min soak, acetone 50% by volume, 10 replications.

3/ Plants with infected tubers/total number of plants observed.

Table 2. Effect of phenamiphos, oxamyl and hot water soak in controlling Meloidogyne incognita in infected potato tubers.

Treatment	Exposure time (seconds)[1/] 10	15	20	30	60	120
Phenamiphos 2.37 g a.i./l	1	1	1	1	1	1
Oxamyl 5 g a.i./l	-	1.8	1.5	1.5	1.2	1.0
Hot water soak[2/] 45°C	2.5	-	3.6	2.3	2.3[3/]	1.8[4/]
60°C	1.2	-	1.6	1.5	-	-
Control	3.7	3.7	3.7	3.7	3.7	3.7

1/ Root galling index derived by rating 1 to 5 as 1 = no root galling and/or nematode reproduction to, 5 = very severe root galling and/or a very high nematode reproduction.

2/ Exposure time in minutes unless indicated otherwise.

3/ Exposure time 40 min.

4/ Exposure time 50 min.

Table 3. Effect of Phenamiphos, Oxamyl and hot water soak in controlling Meloidogyne incognita in infected potato tubers.

Treatment	Exposure time (seconds)[1/] 10	20	30	60	120
Phenamiphos 4.75 g ai/l	1	1	1	1	1
Oxamyl 10 g a.i./l	1	1	1	1	1
Hot water soak[2/] 45°C	2.5	3.6	2.3	2.3[3/]	1.8[4/]
60°C	1.2	1.6	1.5	-	-
Control	3.7	3.7	3.7	3.7	3.7

1/ Root galling index derived by rating 1 to 5 as 1 = no root galling and /or nematode reproduction to, 5 = very severe root galling and/or a very high nematode reproduction.

2/ Exposure time in minutes unless indicated otherwise.

3/ Exposure time 40 min.

4/ Exposure time 50 min.

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TESTS FOR TRANSMISSION OF FOUR POTATO VIRUSES THROUGH POTATO TRUE SEED

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Potato breeders often exchange their breeding materials internationally in the form of true seed and potato gene banks are normally maintained in this form.

Presence of non-indigenous viruses in potato true seed therefore poses a quarantine problem, particularly for countries distant from the parts of American continent where tuber-forming Solanum species and those potato viruses which depend primarily on them for survival originated (Jones, 1981a). Fernow et al. (1970) and Singh (1970) demonstrated that potato spindle tuber viroid (PSTV) is readily transmitted through potato true seed, but the only viruses that have so far been shown to be true seed-transmitted are Andean potato latent virus (APLV) and potato virus T (PVT). APLV (Fribourg et al. 1977; Jones and Fribourg, 1978) was transmitted at a low level through seed of a clone of S. tuberosum sub. sp. andigena (Jones and Fribourg, 1977) and PVT readily in both seed and pollen of the wild potato species, S. demissum (Salazar and Harrison, 1978). This paper summarises and discusses the results of (1) further tests for passage of APLV and PVT through potato true seed and pollen; (2) investigations into the seed and pollen transmissibility of the Andean potato calico strain of tobacco ringspot virus (TRSV-Ca) (Fribourg, 1977) and of the oca strain of arracacha virus B (AVB-O) (Jones, 1981b; Jones and Kenten, 1981); and (3) a study of the potential of enzyme linked immunosorbent assay (ELISA) as a routine test for use by quarantine authorities to intercept batches of infected true seed. APLV, PVT, TRSV-Ca and AVB-O affect potato in the centre of origin of the crop in the Andean region of South America but seem not yet to have become established elsewhere (Fribourg, 1980; Jones, 1981a; Jones, Fribourg and Slack, 1981).

TRSV-Ca was detected in 2 to 9% of potato seedlings grown from batches of true seed from plants of cv. Cara and clone G5998(6) infected with TRSV-Ca. Similarly, a potato isolate of AVB-O was detected in 4 to 12% of progeny seedlings of cv. Cara and clone D42/8 infected with AVB-O. PVT passed through 33 to 59% of seed from PVT-infected cv. Cara, but only 0 to 2% infection was detected in seedlings from seed of PVT-infected clone D42/8. By contrast, no infection was detected in seedlings grown from seed from plants of G5998(6), D42/8 and cv. Cara infected with APLV strains Hu (APLV-Hu) or Caj (APLV-Caj), although both strains passed through seed of Nicotiana clevelandii.

AVB-O, PVT and TRSV-Ca were detected in all tests on pollen from flowers of infected potato plants; APLV-Caj and APLV-Hu were detected less frequently. AVB-O and PVT were transmitted through 2% and 8% respectively, of seed from healthy potato plants pollinated with pollen from infected plants. However, no transmission through seed was detected when pollen from TRSV-Ca infected plants was used. None of the four viruses were transmitted to healthy potato plants pollinated with pollen from infected plants.

APLV-Hu caused exceptionally severe symptoms in the cv. Cara plants used for seed production, but the Bolivian strain of PVT induced only mild symptoms rather than the severe systemic necrosis previously reported for the type strain of PVT in this cultivar. No symptoms developed in potato seedlings infected with TRSV-Ca, AVB-O or PVT through the seed.

In the work summarised above, virus presence was determined by infectivity tests supplemented where necessary by gel diffusion serology; where bulk sampling of seedlings was used, percentage seed transmission was estimated using the formula of Gibbs and Gower (1960). The possibility of using ELISA as a routine test to intercept batches of infected true seed instead of relying solely on labour-intensive infectivity tests on seedlings was investigated using seed from TRSV-Ca infected mother plants as a model system. When infected seed batches were grown on and duplicate samples of seedlings tested for TRSV-Ca either by ELISA or by inoculation of sap to N. clevelandii, both methods gave the same results. However, when extracts from single ungerminated seed were ground up and tested by ELISA the virus was found in a far greater proportion of them (up to 80%) than actually gave rise to infected seedlings (2-9%). This is presumably because in many seeds produced on infected plants the virus is only present in the testa or endosperm, while only seed that contains virus in the embryo will produce infected seedlings. The proportion of ungerminated seeds carrying virus detectable by ELISA varied considerably with batch and seed line. Most affected seeds contained a small amount of virus, their extracts giving optical density values close to the ELISA 'detection threshold'. Whether the small proportion of seeds whose extracts give high optical density values are the ones which give rise to infected seedlings remains to be determined.

Apart from PSTV (Fernow et al., 1970; Singh, 1970), none of the viruses or virus-like diseases affecting the potato crop in temperate regions of the Northern Hemisphere has yet been shown to be transmitted through potato true seed. Therefore, seed has long been considered by potato breeders to be relatively safe to use both when exchanging breeding materials internationally and for storing germplasm of tuber-forming Solanum species in gene banks. However, the results summarised here and reported in detail by Jones (1982) clearly demonstrate that three viruses (AVB-O, TRSV-Ca and PVT) that affect potato in the centre of origin and diversity of the crop in the Andean region of South America readily pass through seed of S. tuberosum. Quarantine authorities and breeders should therefore be aware that these viruses may be present when breeding lines and germplasm are obtained from South America either directly or indirectly via gene banks. Infected seed batches can be intercepted by growing samples of seed and testing the seedlings by inoculation to appropriate indicator hosts and/or by ELISA. Alternatively, at least with TRSV-Ca, a considerable saving in time and labour can be obtained by direct testing of ungerminated seed by ELISA. Serious consideration should be given to making such checks mandatory (1) before individual seed lines are distributed from potato gene banks and (2) on all new imports of potato seed. The finding that AVB-O and PVT are transmitted through pollen to seed produced on healthy plants of S. tuberosum is also important. To ensure complete freedom from these viruses in seed for distribution, it will be necessary to test both parents (all male parents where bulk pollinations are used) for them rather than just the mother plants on which seed is set.

Depending on seed batch and on the clone of S. tuberosum used for seed production, considerable differences were found in the efficiency of virus transmission through true seed. This was particularly marked with PVT. Thus, at one extreme a batch of seedlings grown from selfed cv. Cara seed was 59% infected with this virus, whereas at the other extreme no virus was detected with one of two batches of seed produced by selfing PVT-infected plants of D42/8. Hanada and Harrison (1977) suggested that the temperature at which infected plants are kept during the setting of seed is important in determining the level of seed-transmission. The temperature in the glasshouse varied widely during the period when the potato seed I used was produced, so temperature variation is a probable cause of the differences in transmission obtained between different seed batches produced on the same clone. Jones and Fribourg (1977) found that APLV passed through about 1% of seed collected from infected potato plants growing in the field at high altitude in the Andes where conditions are cool, particularly at night (Jones, 1981a). APLV is adapted to multiply best in plants under cool conditions. The failure here to obtain any seed-transmission of APLV-Caj or APLV-Hu may therefore have been because of too high a temperature in the glasshouse during production of seed.

Passage of viruses through true seed would not be expected to be an important method of spread in the field in a vegetatively propagated crop like potato. It may, however, play an important role in the spread of AVB-O, PVT and TRSV-Ca in wild potato species which depend on true seed for dispersal (Jones, 1981a).

Acknowledgments

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POTATO PRODUCTION BY TPS IN A TEMPERATE REGION

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Introduction

The advantage of potato production by TPS is that countries lacking certified seed programs can produce potatoes without importing seed tubers. Many tropical and sub-tropical countries do not have land where aphid populations are low enough to maintain a certified seed program. In Korea, potato growers mainly depend on the seed tubers produced at highland area, but only 10% of total production area can be provided with the certified seed, since the acreage of highland is limited. Thus, the use of TPS for potato production and for seed potato production is invaluable to compensate for the certified seed program.

TPS cultivation up to now, almost exclusively depends on the practices of growing seedlings and transplanting. Many vegetable crops, i.e., tomato, cucumber, and Chinese cabbage are transplanted from nursery to field. There is no doubt that farmers can handle TPS as easily as they did vegetable seeds.

The potato cropping system in Korea is divided into two seasons, spring and fall, to avoid hot and humid summer (Figure 1). In spring, farmers plant tubers as early as possible and harvest between the last week of June and the first week of July to protect products against heavy rainfall.

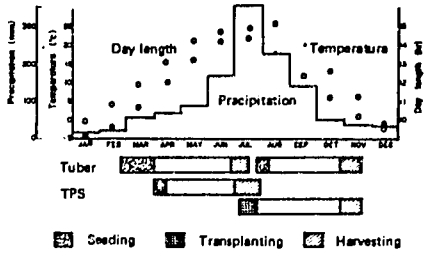

Figure 1. Mean temperature, precipitation and day length in Suweon, Korea and the cropping system for tuber planting and true potato seed.

The temperature rises and day length increases toward the end of the cropping season, thus, hastening senescence of potato vines. The situation is completely reversed in fall. Sprouted tubers are planted on August and harvested after the first frost which ends the cropping season. If tubers are planted in July, they will rot due to high temperature and high soil moisture. An additional problem is the supply of seed tuber, since the seed tubers for the fall season are produced in spring. With TPS, extension of the fall cropping season seems possible. TPS can be stored easily for long time and seedlings stand well under high temperature of 25°C. High moisture content in soil would be helpful to establish the transplants. Therefore, feasibility of TPS cultivation as a fall crop has been intensively studied.

1. Yield potentiality of TPS populations derived from various crosses.

Most of the available material at the Horticultural Experiment Station has been used to produce TPS populations, and their performances in terms of yield, and uniformity, have been determined (Table 1). TPS populations produced higher yields in fall than in spring.

The performance of several high yielding crosses from both spring and fall trials are presented (Table 2). In spring, no TPS population exceeded Irish Cobbler for marketable yield. However, many crosses out-yielded Irish Cobbler when total yield was compared, indicating the potentiality of TPS population and possible improvement through a slight modification of agronomic practice and intensive selections for high yielding crosses. In fall, C047 (4x x 4x) and F008 (4x x 2x) gave a marketable yield of 34.7 t/ha while Dejima yielded 28.7 t/ha. Uniformity of TPS populations were, in many crosses, high enough to be released as horticultural varieties.

The relationship between yield and yield component characters for TPS performances was clarified. In spring, the total number of tubers was more widely distributed and the mean of 23 populations was higher than in fall cropping. However, the number of marketable tubers was much higher in fall than in spring. It is probable that the increase of marketable yield in fall compared with spring is largely due to the increase in the number of marketable tubers. Additional evidence comes from the fact that much closer linear relationship (the coefficient of determination was 0.92 and 0.87 in spring and fall, respectively) was obtained between marketable yield and the number of marketable tubers per plant, rather than the average

Table 1. Mean and range of variables in 23 TPS populations.

Cross	Tubers (total no.)	Marketable tubers		Yield	
		No. 1/	Av. Wt. g.	Total (g/ plant)	Marketable (g/ plant)
Spring					
Mean	20.8	3.2	73	567	241
Maximum	31.1	5.5	97	925	469
Minimum	8.8	0.6	59	217	43
Range	22.3	4.9	38	708	426
Fall					
Mean	16.0	5.2	93	918	487
Maximum	20.8	8.5	126	1,123	878
Minimum	10.0	2.1	70	332	182
Range	10.8	6.4	56	791	696

1/ Over 50 g.

Table 2. Evaluation of high yielding populations.

Populations	Stand	Uniformity 2/	Yield 1/ A	Yield 1/ B	A/B
	%				%
Spring crop 3/					
Cv. x Cv.					
C056	99	H	21.6	43.5	50
C067	100	H	22.3	35.6	63
C035	100	M	23.9	37.5	64
Cv. x FDR clone					
F009	100	M	15.4	37.8	41
O.P.					
S009	100	M	14.7	32.8	45
S025	97	M	17.0	37.3	46
Tuber					
Irish Cobbler	100	H	29.6	36.4	81
Fall crop 4/					
Cv. x Cv.					
C067	78	H	32.6	37.2	88
C047	93	H	34.7	46.1	75
C058	85	H	25.6	36.3	71
Cv. x FDR clone					
F008	85	M	34.7	45.4	76
O.P.					
S025	74	L	16.7	24.0	70
Tuber					
Dejima	95	H	28.7	31.3	92

1/ A = marketable yield (tonnes per hectare; B = total yield (tonnes per hectare)
2/ H = high; M = moderate; L = low.
3/ TPS seeding, March 5; transplanting, April 8; harvesting, July 30.
4/ TPS seeding, June 3; transplanting, July 7; harvesting, October 23.

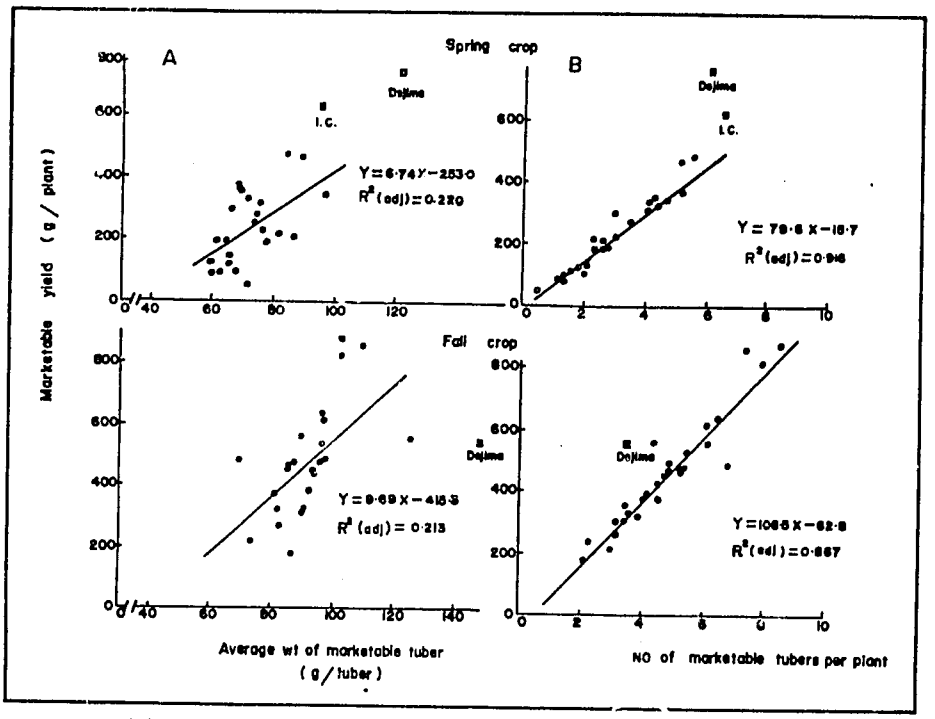

Figure 2. (A) Distribution of TPS populations plotted according to the average weight of marketable tubers and marketable yield per plant. (B) Distribution of TPS populations plotted according to the number of marketable tuber and marketable yield per plant.

weight of marketable tubers (Figure 2). Both number of marketable tubers and the average weight of marketable tubers provided highly significant correlation coefficients with marketable yield in both the spring and the fall crop. Also, highly significant correlation coefficients were obtained between the two seasons except for the average weight of marketable tubers.

The comparison of groups divided by their parental materials and crossing methods is presented in Figure 3. In general, TPS populations derived by artificial hybridization gave much higher tuber yield than those by open-pollination or selfing in both spring and fall trials. One important result is that genetic diversity is very important for increasing yield, assuming that open-pollination results mostly in selfed seeds. Also, the result indicated that both total and marketable yield were higher in fall than in spring.

2. Seed setting ability.

For the TPS program, seed production is as important as the tuber yield per se.

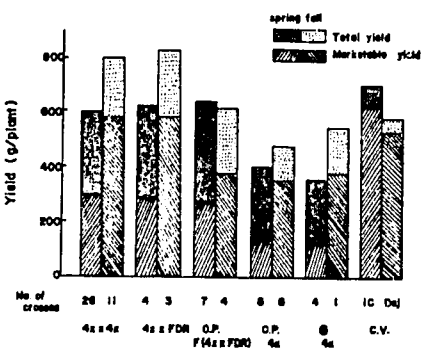

Figure 3. Comparison of total and marketable yield among crossing groups in spring and fall.

The cross, K6-32 x A4P130B-1 produced 300 seeds per berry (Table 3). Certain open-pollinated clones produced more than 360 seeds per berry. The weight of 1,000 seeds is 0.51 g. Thus only 36 g. of seed (or 240 berries) are necessary to grow plants for one hectare. We believe 10 or 15 plants are quite enough to produce 240 berries. To increase the efficiency of hybrid seed production, the utilization of male sterility is now under investigation.

Concluding Remarks

The results obtained at HES for two years indicated that the potentiality of potato production by TPS was indeed remarkable. Many TPS populations out-yielded leading cultivars in the fall. Agronomic practices were relatively easy. This year, it is planned to provide small amounts of TPS to farmers, and the problems related to TPS cultivation on the farmers' own land are to be investigated.

Selection of relatively high yielding populations produced by open-pollination is the first step in establishing a TPS production system. Meantime, we are investigating male sterile clones at least to eliminate the tedious emasculation procedure for F_1 hybrid seed production. In addition, various attempts will be given to induce natural hybridization both in field and in net-house.

Table 3. Seed setting ability in some crosses.

Year and crosses	No. of flowers pollinated	No. of fruit harvested	No. of seed per fruit
1980			
York x Cherokee	14	9	183
B8284-1 x W5337.3	10	5	59
1981			
K6-32 x A4P130B-1	16	3	300
T39-4 x T39-8	30	6	172
K1-22 x T39-22	18	17	144

POTATO FOR HOT DRY TROPICS

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With the century 2100 ahead scientists are busy planning to augment new resources to feed enlarging populations and thereby shrinking land equivalents. Such planning aims to fit with crop planning in relation to eco-system maximum land use planning, agroforestry, and diversification to focus attention to increasing requirements of energy to enhance productivity. This exercise is necessary to find new areas but also to adjust crop production sequences and develop new varieties for production increase to meet the challenge. This leads to inter-disciplinary coordinated approach between scientists, input suppliers, and policy makers.

Our past experience with introduced hybrid maize, dwarf wheat, and paddy rice varieties has shown that such new genotypes trigger changes which gives best increase of yield in different environments by judicious selection of the developed high yielding hybrids. The farming community loses no time to take up such varieties and technology, for example prompt use of new varieties of the above crops and potato and "Seed plot techniques" in India, to increase yields. In India various agricultural programmes such as IADP and others have accepted a challenge to get more food per unit area/time as well as plant breeders and scientists dealing with ecology, energy, economics, and employment. The same now should be adopted in Bangladesh and Ceylon and South Mediterranean countries where conditions are similar to India.

One of the priority strategies of the International Potato Center along with true seed is to produce potato varieties for hot humid tropics. But so far no efforts have been made to develop varieties for the vast areas of the hot dry tropics which are dependent on irrigation and to spread the results of this to marginal farmers. The objective in both cases being to select varieties which give optimum yields in shortime periods having a temperature conductive to tuberization and selection of rapid bulking early maturing varieties. The present study focuses attention on hot dry tropics so as to liberate new low rainfall areas for potato cultivation and to provide multiple cropping where potato fits well as an intercrop. Such areas of India are around Rajasthan-desert, Punjab, Haryana, and Western U.P. and in many other countries. Such other programmes show that potato has a flexibility and versatility to fit itself in any sequence where the correct variety, land, temperature, and irrigation are available. Keeping this in view a preliminary study was conducted to identify correct genotypes which are not affected by high temperature and fit in with the high intensity cropping pattern of the areas of India indicated above.

Materials and methods

The area selected for this study was Punjab where in September the temperature is around 90°F and there is little rain as compared to normal potato planting time in the first week of October when it is below 80°F. The object was to bring the date of planting of potato as close to mid-September as possible to use potato as an early crop without disturbing the established normal sequence of intensive cropping. It is customary to start planting early potatoes by mid-September and the normal crop by the second week of October, when temperatures are still high and humidity very low due to absence of rain (Figure 1).

Twenty hybrids of potato from advanced selections ready for final assessment for release were planted on northern slopes in two rows of 10 tubers each on two dates, 20th September and 10th October. Weekly observations were made on germination, growth, and any plant abnormality. In a second experiment shade was created by growing maize and Bajra in between the rows on the south side of the ridge and bending the plants over potato for shade.

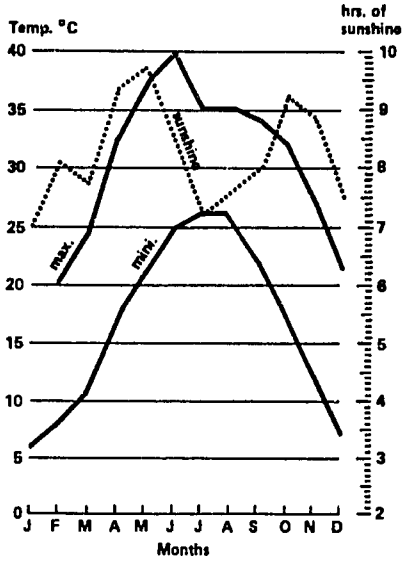

Figure 1. Average 1979 monthly temperature and sunshine hours in the Punjab potato producing area. Source: Weekly Weather Reports and Meteorological Monograph-Climatology/No. 3/1972 - Sunshine Over India, Indian Metereological Department, Government of India.

Seed tubers when kept in shade and well sprouted were planted on both the above dates. The data on the % germination and % plants having tip burn and yellowspots on the leaves and lanky growth due to hot soil and high temperature were recorded. The rows were irrigated to one-half height of ridges in nights only when required. (Table 1).

Observations

From the hot soils (Table 1) the first 10 genotypes did not show any tip burn in September. In contrast the latter 10 had between 10 and 59% tip burn. The same genotypes planted in October showed no such symptoms. Germination fluctuated between 72-97% in the September planted crop and 65-100% in the October crop. Of all varieties planted October 10, no plant showed tip burn and the other characters listed above. Germination in each genotype was higher in the October planting compared to the September planting.

Table 1. Percent germination and percentage plants affected by high temperature in early and normal plantings.

Hybrid variety	September plants		October plants	
	Germination %	Heat damaged No.	Germination %	Heat damaged No.
C 3816	95.00	0.00	95.00	Nil
E 1100	72.50	0.00	87.50	-
E 4451	77.50	0.00	92.50	-
F 1277	91.25	0.00	97.50	-
F 1341	77.50	0.00	97.50	-
F 2426	73.75	0.00	92.50	-
F 6370	76.25	0.00	92.50	-
JC 900	86.25	0.00	95.00	-
EM/B 859	97.50	0.00	98.75	-
Craigs Defiance	75.00	0.00	87.50	-
A 7416	81.25	17.00	87.50	-
C 990	92.50	31.08	97.50	-
C 2703	87.50	10.00	100.00	-
C 3721	80.00	15.60	97.50	-
F 5134	31.25	44.00	65.00	-
JC 7241	87.50	37.68	85.00	-
EM/C 1021	85.00	20.60	97.50	-
K. Alankar	65.00	50.00	83.75	-
K. Jyoti	80.00	53.10	92.50	-
UTD	88.75	59.68	90.00	-

Symptoms of heat injury were:
sprouts - few to many. Tips usually deformed showing tip burn;
stems - elongated, growth rapid with weak plants;
Leaves and leaflets - Leaflets dropping and yellowing at the margins. In about 3-5 days, yellowing is replaced by browning and eventually death in affected parts. The dead area starts from the tips or margins extending inwards, until in extreme cases the whole leaflet is killed. Older and horizontal leaves suffer more the the younger and upright ones.

Plants showed recovery from these effects under favorable conditions. Recovery however, was seldom complete.

To determine if these symptoms were due to viral infection, the top leaves from affected plants were wedge grafted to plants of Kufri Chandramukhi raised from virus-free tubers. No evidence of graft transmission was obtained after two months and these symptoms were not sap transmissible. Further more tubers obtained from affected plants were planted during January and produced normal plants.

Mean temperatures for September and October (Figure 1) show that there is a considerable fall in the minimum temperature during the first half of October when germination is high and the growing plants do not show any of the above morphological variations. Therefore, it can be concluded that the effects on foliage are due entirely to the prevailing high temperatures on both soil and atmosphere. From the practical point of view these observations are of definite value to a breeder in that many hybrids can be screened out for growing during September under high temperature conditions.

An experiment was designed to enhance the germination of the variety Kufri Chandramukhi using different methods of preventing heat and to determine if the effect on the foliage could be reduced. For this the Kufri Chandramukhi crop was planted in a replicated trial using four treatments. While some the plants of each treatment did get the above symptoms, the hightest incidence of heat damage was in the uncovered treatment (Table 2). It is concluded that suitable high yielding genotypes can be selected to fit the market demand of fresh potato at an economically beneficial period.

Table 2. Percentage of germination and percentage of plants affected by heat in variety - Kufri Chandramukhi, planted on 20-9-1970 at Jullundur.

Treatment	% Germination	% Plants affected
Maize stock cover across ridges	95.00	43.27
Shade of bajra (P. typhoideum)	96.10	28.32
Shade of bajra bean over	97.78	25.00
Tubers kept in shade and planted on 26-9-70, when well sprouted	96.67	31.03
Uncovered	94.34	30.00

References

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Walker, J.C. 1948. Diseases of vegetable crops. McGraw Hill pp. 320-392.

OBTAINING AND RAPID MULTIPLICATION OF DISEASE-FREE POTATO SEED TUBERS IN ETHIOPIA

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Potato is a valuable food crop and can grow in different climatic conditions. Conditions of Ethiopian high lands fully respond to the demand of the potato plant where around 30 thousand hectares are grown. The most common varieties were introduced from abroad during 1940, and lost their quality due to low yield and high susceptibility to potato late blight.

Nowadays potato production is hindered due to absence of seed of varieties which give a high yield and are resistant to late blight. It is true that trials of hybrids in the International Potato Center are conducted over a number of years with the objective of evaluating yield and resistance to late blight. Dr. Haile Michael from Alemaya college is carrying out the trial in different agro-climatical conditions of Ethiopia. Many clones with different qualities were identified by them. However the potato samples were infected by virus and bacterial diseases during the trial. For initial seed production work of new varieties firstly it is very essential to eradicate virus infection.

The most prevalent viruses are X, S, M virus. Starting from 1980 eradication of virus infection from promising varieties using methods of meristem culture and rapid multiplication of disease-free potato is carried out in the Scientific Phytopathological Laboratory Ambo.

Materials and methods

Three varieties were taken for eradication of virus infection: AL-204; AL-253; AL-563 which have X, S, M virus and bacterial wilt. Germinated tubers were subjected to a temperature 35-37°C for 4-7 weeks. After this from each sample, 24 to 33 meristem tips with a size of 0.15-0.30 mm will be excised in a sterile box. The nutrient media is composed of basal salts, major and minor elements and organic supplements by Murashige and Skoog, plant growth regulators; 0.2 mg/l JAA, 0.5 mg/l GA, 0.04 mg/l kinetin.

Growing of the isolated meristem will be carried out in artificial light 8000 lux, length of photoperiod 13-14 hrs and temperature at night 20-22°C, daytime 24-26°C. The grown plant will be indexed initially for virus at the time they are transferred from the culture medium to soil. A single leaflet will be removed from the plantlet and tested by mechanical sap inoculation onto indicator plants, by serological tests, and by electron microscopic examination.

Plants free from virus infection will be multiplied by stem cuttings in test tubes, rooted cuttings transplanted to pots and these in turn will produce more cuttings. Using chemicals (rindit) for dormance period breaking of tubers.

Further during the rainy season (June to September) disease-free plants will be multiplied in field conditions as tubers, as plantlets from tubers, or as stem cuttings. In order to indicate absence of virus infection, during the vegetative period, visible and serological testing will be carried out.

Results and discussions

Nutrient media with the addition of 0.5 mg/l GA, 0.2 mg/l JAA, 0.04 mg/l kinetin, pH 5.7, and 0.7% agar Difco is the most favorable for growing isolated meristems for further potato plant multiplication. Within 4-5 months after the isolation of meristems potato plantlets were obtained. Production of plants free from virus infection by heat treatment increased by 27.4%, following heat treatment, however at the same time vitality of meristem on the media decreased. Average percent of vitality with heat treatment was 69.1%, without heat treatment- 87.5% and this depended on variety (Table 1). Size of isolated meristems free from virus infection increased to 0.3 mm due to the heat treatment.

Virus-free plantlets were rapidly multiplied by using the stem cutting method in tubes. Cuttings were planted in solid and fluid media. In fluid media the quantity of major and minor elements, Fe-helat was reduced ten-fold in comparison with that of agar media, and that of plant growth regulators of 3 mg/l JAA, pH 5,7. All organic components of media were expelled in order to avoid contamination of media. The cuttings planted on a filter-paper bridge formed root systems and shoots within 5-7 days. After 20 days plantlets were already higher than the height of test tubes, then they were cut and were planted in the fluid media again.

Table 1. Influence of heat treatment on meristem vitality and quantity of generated plants free from diseases.

Sample and treatment 2/	Isolated meristems		Disease-free plants	
	No.	Vitality 1/	No.	%
AL-204				
HT (38)	33	26	22	85
NHT	24	20	8	40
AL-563				
HT (40)	24	10	10	100
NHT	24	21	16	76
AL-253				
HT (55)	24	20	18	90
NHT	24	22	15	68
Total				
HT	81	56	50	89
NHT	72	63	39	62

1/ Index of general vigor.

2/ HT = heat treatment, days of treatment in parenthesis.
NHT = no heat treatment.

During the first cutting planting, 15% of media was infected, but for later planting infection of media was not evident. The using of this multiplication technology significantly simplifies the nutrient medium preparation work, transplantation of plantlets into the soil, etc.

The direct growing in the field conditions during the rainy season is possible through multiplication of disease-free potato by stem cuttings. Yields of tubers were 746.4 g per plant. June is the most favorable season in Ambo for planting of rooting cuttings. One mother plant produces an average of 50 cuttings in 40 days.

Rindit (0.5 cm^3/kg of tubers with exposure of 30 hrs) is the most favorable preparation for the interruption of dormancy period of harvested tubers. The period from tuber harvesting until its planting after using of rindit required 24-30 days. Reinfection under field conditions during the rainy season was practically absent. Winged aphids on the potato plants were absent, but wingless aphids were discovered on the lower leaf story to the end of rainy season (September) and averaged from 0.5 to 1 per plant.

Conclusion

The investigation demonstrates effectiveness of the above-named methods for obtaining and multiplication of disease-free material under Ethiopian conditions and makes possible initiation of the production of disease-free potato stocks.

RESEARCH ON POTATO CULTURE IN THE MIDDLE AND LOW ELEVATION IN INDONESIA

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Potatoes are currently grown mainly in the highland. Continuous potato growing in limited areas of highlands causes accumulation of pests and diseases that induce higher costs of crop protection. Labor is increasingly expensive and stable manure is another costly input in the highlands. High price and increases in production of potatoes indicate a strong demand especially in the urban areas. One of the efforts to increase the production which should result in a more moderate price is to develop heat tolerant varieties and research on agronomic management techniques used in the middle and low elevations. There are about 300,000 hectares of irrigated or rainfed, bunded rice production areas at elevations ranging from 500 to 750 meters in Indonesia. Experiments in progress showed a promising result in the middle elevation of 700 meters. This research is a part of the "Tropical Agronomy for Potatoes", a special project of SAPPRAD (Southeast Asian Program for Potato Research and Development) in Indonesia.

Research activities that will be conducted:

1. Variety screening and introduction of heat tolerant varieties.
2. Research on agronomic management techniques to alter the temperature and moisture content of the soil.
3. Integrated pest control especially to bacterial wilt.
4. Multilocational trials with recommended varieties.
5. Transfer of technology to farmers.

Effects of shade on yield

At Muara 260 m, the vegetative growth was vigorous but later on plants progressively wilted. Wilted plants were rogued until they reached 30% in variety Rapan 106 and 71% in Cosima. Potatoes were grown in the rice field with poor drainage that induced disease infection. Yields were low (Table 1), nevertheless plants formed tubers in the lowland. There were no consistent differences in yield among open and shaded plots. In the next experiment the plots should be elevated with the application of soil pesticides to prevent pests and diseases.

Table 1. Wilt incidence and potato yields at two locations with and without shade, West Java, Indonesia, November, 1981.

Location and Treatment	Wilted plants %	Productive (No)	Wt. of tubers per plant (g)
Muara (260 m)			
Rapan 106			
Open	26	103	50.49
Shaded	33	73	59.68
Cosima			
Open	73	27	179.70
Shaded	70	28	154.96
Cimangkok (700 m)			
Rapan 106			
Open	6	225	118.80
Shaded	9	205	69.92
Cosima			
Open	15	486	87.73
Shaded	13	463	99.02

At Cimangkok, 700 m, the percentage of wilted plants was lower than at Muara, 7.5% in Rapan 106 and 14% in Cosima. Cosima was more susceptible than Rapan 106 in both locations. Weights of tubers per plant were still low.

Cosima in the Chimangkok experiment was also planted with treatments of subplots with furrows and hilled versus flat, both were mulched or unmulched, and shaded with corn plants versus open as main plots (Table 2). This preliminary experiment showed that without shade, flat plots produced higher yield than hilled plots. On the other hand hilled plots produced higher yield than flat plots in the shade. There was no significant difference either among subplot nor between mainplots, but there was interaction among the treatments.

Table 2. Potato yields of Cosima with flat versus ridged culture, with and without shade, Cimangkok, West Java, Indonesia, November 1981.

Treatment	Kg/plot		g/plant	
	Open	Shaded	Open	Shaded
Ridge	2.23	3.18	66.81	96.33
Flat	3.52	2.24	118.32	99.65
Ridge + Mulch	1.92	4.50	67.28	128.28
Flat + Mulch	2.88	1.88	98.51	71.84
Interaction				
HSD 5% Ridge vs Flat :		2.06		52.84
Open vs Shade:		2.02		48.07

INCREASING HETEROZYGOSITY AND TUBER YIELD THROUGH THE 2n GAMETE BREEDING APPROACH IN POTATOES

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International Potato Center

Introduction

Synthesis of tetraploid potatoes from diploid-diploid matings provides a unique breeding method with great potential to improve tuber yield in potatoes, provided the occurrence of 2n gametes with the sporophytic number of chromosomes. Among all meiotic mutants which produce 2n gametes; the most required is a recessive mutant named parallel spindles (ps/ps). The genetic significance of parallel spindles is essentially a first division restitution mechanism (FDR). Diploid spores of this type (FDR), preserve 75 to 80% of heterozygosity of the parent, and heterozygosity is transmissible to the offspring intact. It is obvious that larger fractions of the intralocus interactions, associated with dominance variation, and interloci interactions associated with epistatic variation are maintained. The assembling of the two FDR 2n spores by sexual means (syngamy), would increase heterozygosity, provided the diploid hybrids come from unrelated parental diploids. Furthermore, both types of allelic interactions will be increased in the arising tetraploid. However, the most important interactions will be the intralocus type, where four alleles per locus will create different orders of interactions (diallelic, triallelic, tetrallelic), which highly correlates with heterosis.

Preliminary evidence of this matter has been reported by Mendiburu et al., (1974), and for the first time involving cultivated Solanum groups in the present paper.

Materials and methods

Four Solanum groups - tuberosum haploid, andigena haploid, phureja and stenotomum - were used. Hybrids among these diploid groups were made earlier and samples within hybrids were taken as females and bulk pollen of equal number of plants per hybrid, as males. These hybrids were used in crosses with a sample of tuberosum cultivars (unilateral sexual polyploidization; 4x x 2x, 2x x 4x). Selected individuals within hybrids, that produce 2n eggs and 2n pollen, were also intercrossed to produce tetraploids (bilateral sexual polyploidization, 2x x 2x).

Preliminary evaluation of the resulting progenies from unilateral sexual-polyploidization were carried out in two different environments (San Ramón and Huancayo, 1981). Individuals per family were tuber increased and planted in 10-hill plots at 0.90 m between rows and 0.30 m between plants. Total tuber yield in gr/plant was recorded. Regular cultural practices were followed along the growing season in both locations.

Table 1. Yield performance of selected diplandrotetraploid and diplogynotetraploid clones at San Ramón 1981 (10-hill/plot).

Cross[1/] Genome[2/] and (No. of clones)	Range of plant wt. (g.)	Plant weight av. (g.)	Tuber weight av. (g.)
4x x 2x			
Kenn x (AH x STN)			
TTAS (1)	787	787	53
Kenn x (STN x AH)			
TTSA (1)	1170	1170	78
Kenn x (AH x AH)			
TTAA (8)	703-923	808	43
Kenn x (PHU x AH)			
TTPA (4)	977-1433	1145	64
Red P. x (STN x AH)			
TTSA (2)	883-1200	1042	56
Red P. x (AH x AH)			
TTAA (4)	770-1285	989	55
Onta x (AH x AH)			
TTAA (1)	750	750	43
Onta x (AH x PHU)			
TTAP (1)	893	893	55
Katah x (AH x AH)			
TTAA (4)	731-1238	880	48
Katah x (AH x PHU)			
TTAP (1)	1190	1190	44
2x x 4x			
(AH x AH) x Tub bk.			
AATT (1)	790	790	45
(AH x STN) x Tub bk.			
ASTT (3)	736-833	798	56
Adapted Clones (controls)			
LT-1			
TTTT		692	92
DTO-28			
TTTP		578	92

1/ Kenn = Kennebec
Red P. = Red Pontiac
Onta = Ontario
Katah = Katahdin

2/ T = tuberosum genome
P = phureja genome
A = andigena genome
S = stenotomum genome

Results and discussion

Yield performance of diplandrotetraploids (4x x 2x), and diplogynotetraploids (2x x 4x), are compared to adapted clones to lowland tropics (Table 1). The average tuber weight per plant for both 4x x 2x and 2x x 4x hybrids was higher in all cases than the controls; however, the average tuber weight was lower than adapted clones. In the highlands (Table 2), the total tuber yield per plant and average tuber weight for both 4x x 2x and 2x x 4x hybrids was higher significantly as compared to San Ramón. Controls were not included in Huancayo. However, the average tuber weight per plant of most hybrids was as good as the best advanced clones selected for the highlands.

The total tuber yield of both diplandrotetraploids and diplogynotetraploids based

Table 2. Yield performance of selected diplandrotetraploid and diplogynotetraploid clones at Huancayo 1981 (10-hill/plot).

Cross[1/] Genome[2/] and (No. of clones)	Range of plant weight (g.)	Plant weight av. (g.)	Tuber weight av. (g.)
4x x 2x			
Kenn x (AH x STN)			
TTAS (1)	1250	1250	94
Kenn x (STN x AH)			
TTSA (1)	1550	1550	160
Kenn x (AH x AH)			
TTAA (20)	1000-2680	1450	93
Kenn x (PHU x AH)			
TTPA (4)	1167-1956	1651	99
Red P. x (STN x AH)			
TTSA (2)	1460-1711	1586	104
Red P. x (AH x AH)			
TTAA (3)	1000-2000	1563	79
Red P. x (AH x PHU)			
TTAP (1)	1375	1375	98
Onta x (AH x STN)			
TTAS (1)	1380	1380	73
Onta x (STN x AH)			
TTSA (1)	2257	2257	113
Onta x (AH x AH)			
TTAA (1)	1056	1056	85
Onta x (PHU x AH)			
TTPA (1)	1538	1538	77
Onta x (AH x PHU)			
TTAP (3)	1640-2356	1917	110
Katah x (AH x AH)			
TTAA (6)	1111-2111	1462	77
Katah x (PHU x AH)			
TTPA (1)	1625	1625	81
Katah x (AH x PHU)			
TTAP (1)	1940	1940	76
2x x 4x			
(TH x PHU) x Tub bk.			
TPTT (1)	2120	2120	104
(AH x AH) x Tub bk.			
AATT (2)	1911-2600	2256	75
(STN x AH) x Tub bk.			
SATT (1)	1450	1450	147
(AH x STN) x Tub bk.			
ASTT (8)	1422-2900	1955	132

1/ Kenn = Kennebec
Red P. = Red Pontiac
Onta = Ontario
Katah = Katahdin

2/ T = tuberosum genome
P = phureja genome
A = andigena genome
S = stenotomum genome

the number of different genomes is shown (Table 3). The total tuber yields increase as number of different genomes also increase, with the exception of the 2x x 4x hybrids in Huancayo. However, this could have been due to the low number of hybrids taken into account.

In general, these preliminary data suggesting that maximum heterozygosity can also be achieved by the use of cultivated Solanum groups. Increasing heterozygosity also enhances higher intralocus interactions which highly correlates with heterosis. A possible explanation of the good performance of these hybrids in both the lowland and highland tropics may be the buffering effect of the enhanced intra- and interlocus interactions against the effect of the environment. However, more study is needed to support this hypothesis.

To optimize the use of this 2n gamete approach in potato breeding, it seems important to start by using upgraded agronomic character sources besides the production of FDR 2n pollen. In the present experiment the 2n pollen producers were not selected for their agronomic type. Therefore, most derived tetraploid clones lacked good marketability, though they had high yielding ability.

Table 3. Average yield performance of the total tetraploid population in relation to their genomic constitution, 1981.

Genome[1/]	No. of clones[2/]	Average weight/plant g Huancayo/San Ramón
4x x 2x		
TTAA	42/42	1259/668
TTAS	7/7	1373/807
TTAP	15/10	1452/863
2x x 4x		
TTTP	1/1	2120/619
AATT	2/2	2256/716
SATT	10/4	1787/756

1/ T = tuberosum
P = phureja
S = stenotomun
A = andigena

2/ Huancayo/San Ramón, respectively.

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INCREASING THE ADAPTABILITY OF HIGHLAND TROPIC POTATOES TO SUBTROPICAL LATITUDES

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A new breeding population has been developed at the International Potato Center for the traditional potato growing area in the highland tropics. This population is basically comprised of advanced selections originated from a wide source of germ plasm with resistances to several diseases, pests or environmental stresses. Among the most important factors, selection priorities were given to field resistance to late blight, tolerance to frost, resistance to cyst nematode and resistance to virus Y. The germ plasm sources used comprised primitive cultivars from Solanum tuberosum: group andigena (4x), group phureja (2x), group stenotonum (2x), group ajanhuiri (2x), group Juzepczukii (3x), group curtilobum (5x), modern varieties from group tuberosum, and wide group of wild species introduced as clonal selections from the IR-1 Project at Sturgeon Bay, Wiscosin, and foreign breeding programs.

A long term phenotypic recurrent selection is currently established to maintain genetic diversity within the population and upgrade the frequency of desirable genes. Sub-populations were drawn out to meet specific and common problems of potential country users, particularly earliness for non-Andean tropical highlands and adaptation to subtropical daylengths.

The current population was built under short daylengths that correspond to tropical latitudes. Its performance under increasing daylengths suffers gradually due to the effect of photoperiod in the process of tuber initiation and development. The effects may start from delaying maturity of the crop to complete tuberization failure.

To meet adaptability of this population to subtropical highlands, where daylength is longer than in the tropical highlands, a technique to screen for critical daylength at the seedling stage is being evaluated on a sample of different maturing germ plasm. The following results will be presented as preliminary data on the use of the screening method.

Materials and methods

Two families derived from crosses between late maturing clones from the highland tropic population and clones from the lowland tropic population as source of earliness (374068.4 x bulk LT-XY and 374080.2 x bulk LT-XY); one family derived from an intermediate maturing clone and a clone developed for the lowland tropics (Atzimba x DTO-33). The last two families de. 1 from early materials, one of which is a cross between a group tuberosum variety and a tropical clone (Atlantic x DTO-33) and the other, a cross between two clones adapted to the lowland tropics (LT-2 x Maria Tropical).

Seed of these progenies were sown in flats and transplanted at the seedling stage to 7" pots under continuous light. Eight weeks later half of the families were exposed daily to 16 hours of daylength and half left to continuous light (natural day supplemented with low intensity incandescent bulbs). Leaf node and terminal cuttings (Ewing, 1978) were taken at two weeks and four weeks on different genotypes within the same family. Three cuttings (one terminal and two leaf nodes), from each individual were placed in a modified rooting bench under continuous light. Two weeks later readings on tuberization were taken.

The following scale was used: 1 = shoot development from axillary bud; 2 = stolon with terminal tuber developed from axillary bud; and 3 = sessile tuber developed from axillary bud. The latter 2 and 3, were considered as response to tuber induction and 1 as lack of response.

Results and discussion

Tuber induction (Table 1) for two weeks at 16 hr daylength varies from approximately 15% for late x early, 28% for medium x early, and 70 to 85% for early x early.

Table 1. Tuberization under 16 hr daylength by single-leaf node cuttings from seedlings.

Family and (maturity)[1/]	Exposure time to 16 hr daylight[2/] Tuberization 2 weeks No.[3/]	2 weeks %	4 weeks No.[3/]	4 weeks %
374068.4 x bk LTXY (L x E)	4/28	14.2	5/28	17.9
374080.2 x bk LTXY (L x E)	4/26	15.4	8/26	30.8
Atzimba x DTO-33 (M x E)	12/42	28.6	20/41	48.8
Atlantic x DTO-33 (E x E)	24/34	70.6	30/33	90.9
LT-2 x M. Tropical (E x E)	30/35	85.7	32/34	94.1

1/ E = early, M = medium, L = late maturity of parents.

2/ Cuttings grown 8 weeks before exposure to 16 hr daylength for 2 weeks or 4 weeks, respectively.

3/ Numerator indicates number of cuttings which tuberized/number of cuttings under test.

With four weeks of 16 hr daylength, the tuber induction of some families went slightly higher for all groups. On the other hand, under continuous light (Table 2), the percent of tuberization was reduced considerably with the exception of the first family. The differences between the two dates of cuttings would have been due to seedling age differences.

The preliminary data in the present experiment indicate the potential of this technique in the process of screening for longer daylengths. The minimum length of exposure (two weeks) to 16 hr of critical daylength seems to be adequate to identify genotypes responding to tuber induction. Tuber induction under continuous light may indicate potential for segregation of genotypes capable of tuberizing regardless of the photoperiod effect; although, it may also suggest the effect of other inducing factors such as low temperatures.

The performance of the same families under natural long-day conditions, is currently being evaluated to establish the correlation between the artificial method and natural response prior to its use in our breeding strategy to adapt potatoes to longer latitudes. The widening of the adaptability of the present highland tropic population to longer latitudes will increase its usefulness as demand for this material, particularly with resistance to late blight and frost, increases in subtropical countries.

Table 2. Tuberization under continuous light (24 hr), by single-leaf node cuttings from seedlings.

Family and (maturity)[1]	Exposure time to 16 hr daylight[2] Tuberization 2 weeks No.[3]	%	4 weeks No.[3]	%
374068.4 x bk LTXY (L x E)	6/25	24.0	8/26	30.8
374080.2 x bk LTXY (L x E)	1/22	4.5	2/21	9.5
Atzimba x DTO-33 (M x E)	1/41	2.4	9/42	21.4
Atlantic x DTO-33 (E x E)	13/32	40.6	23/33	69.7
LT-2 x M. Tropical (E x E)	17/28	60.7	26/28	92.9

1/ E = early, M = medium, L = late maturity of parents.

2/ Cuttings grown 8 weeks before exposure to 16 hr daylength for 2 weeks or 4 weeks, respectively.

3/ Numerator indicates number of cuttings which tuberized/number of cuttings under test.

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EFFECT OF SOME PESTICIDES ON *PSEUDOMONAS SOLANACEARUM* IN POTATOES

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The bacterium *Pseudomonas solanacearum* causes bacterial wilt of potatoes and many other crops with worldwide distribution. In some regions in México this disease has been a limiting factor in potatoes. Since quarantine measures and better cultural practices have been implemented in Mexico, this disease has become sporadic.

Fumigants have little effect on this bacterium (Enfinger and Carter, 1976; Enfinger *et al.*, 1979; Jones *et al.*, 1966.), possibly because the pathogen is in depths where these products do not reach. Incidence of disease decreases when solutions of maneb, mancozeb, clorotion and ceresan are applied to the soil. However, substantial losses still occur. Effects of fungicides on *P. solanacearum* "in vitro", under greenhouse and field conditions are described in this paper.

Materials and methods

Evaluation of pesticides with a paper disc technique: Paper discs impregnated with fungicide solutions at the concentrations of 10, 100, 1,000 and 10,000 ppm were placed on CPG medium where the bacterium was grown. After 5 days the inhibition zone was measured. (Table 1).

Evaluation by incubation in water with the pesticide: To a bacterial suspension of 1 x 10^8 cells/ml in water were added fungicides at concentrations of 100 and 1,000 ppm. After 1, 3, 5 and 10 days the bacteria were plated on selective Kelman's medium.

Electron microscope observations: Bacteria were incubated for 24 hrs in a liquid CPG medium into which fungicide was placed at concentrations of 100 and 1,000 ppm. Bacteria were then treated with 1% of phosphotungstic acid and the mixture was than prepared for microscope observations.

Green house tests: Captan, maneb, mancozeb, and thiram were dissolved at 0.5, 5 and 10 g of active ingredient in 50 ml of water and applied over the tuber at the moment of planting. A severity index was calculated as follows.

$$(S.I. = \frac{\text{no. of diseased plants in a week x asigned value for the week}}{\text{total no. of plants}}$$

The yield, number of tubers per plant and number of infected tubers were also evaluated. Soil in 10 pots was inoculated with 50 ml of bacterial suspension of 1x10^9 cells/ml one day previous to planting.

Field tests: Fungicides were applied at 5 gr of active ingredient in 50 ml of water to soil previously drenched with a bacterial suspension of *P. solanacearum*. Severity index was constructed apart from evaluation of percent germination, infection, final percentage of plants with symptoms, percentage of infected tubers, and tuber production per plant.

Results and discusion

Laboratory trials

From all of the 19 fungicides evaluated by the paper disc technique, only captan (Orthocide), maneb (Maurate), mancozeb (Manzate 200), and thiram presented inhibition zones at dosages of 1,000 and 10000 ppm (Table 1). These results agree with the work of El Goorani *et al.* (1978). The best treatments were maneb and mancozeb at 10,000 ppm. Fungicides without evident effect were: carboxin (Vitavax), benomyl (Benlate), carbenadazim (Bavistin), fosfito etilico de aluminio (Aliete), metalaxil (Ridomil), dimethirimol (Milcurb), oxycarboxin (Plantvax), pyricarbolid (Sicarol), pyrazophos (Afugan), quintozene (Terraclor), thiabendazole (Mertect), triadimefon (Bayleton), triadimenol (Baytan), triforine (Saprol), zineb (Parzate) and Agrimycin 100.

Table 1. Efect of various fungicides on *Pseudomonas solanacearum in vitro* in paper discs impregnated with the pesticide.

Treatment	Diameter of inhibition[1] 1,000 ppm cm	10,000 ppm cm
Maneb	0.24 c[1]	1.01 a
Captan	0.0	0.22 c
Mancozeb	0.31 c	0.57 b
Thiram	0.32 c	0.31 c

1/ Treatments with the same letter are not statistically different at the 1% level probability.

All the products evaluated inhibited the growth of the pathogen when incubated in water at 1,000 ppm. (Table 2). With the exception of captan other products were not effective or were bacteriostatic at 100 ppm which agrees with previous information where maneb and mancozeb were only bacteriostatic (El Haley *et. al.*, 1969). Differences in activities of thiram, captan, maneb, and mancozeb could be due to water solubility.

Table 2. Effect of various pesticides at 1,000 ppm on survival of *P. solanacearum* incubated in water.

Treatment	Survival of bacteria[1] Time in days 1	3	5	10
Agrimicin	4	2	1	0
Captan	2	1	0	0
Maneb	4	3	0	0
Mancozeb	4	3	3	1
Thiram	3	0	0	0
Control	4	4	4	4

1/ Number of repetitions where the bacteria had survived from a total of 4 trials.

In all treatments except the control, the bacteria had an atypical form when observed by the electron microscope such as cellular wall rupture with larger granulations than in normal cells. It is possible that *P. solanacearum* was affected in the same way as fungi where the principal points of action were SH groups of proteins (Lyr, 1977; Menzie, 1969).

Greenhouse tests

In general, as dosages were raised, plant height was reduced as compared to the control (Table 3). Maneb produced the greatest inhibition, Captan the least. Disease severity of all the treatments was significantly less than that of the control (5% probability). In some of the treatments, the plants were not diseased (maneb, at 1 and 10 g/plant; captan, 10 g/plant; and mancozeb, 5 to 10 g/plant). Diseased plants in the control first became evident during the second week. In the least effective chemical treatments, diseased plants developed in the fourth week. These treatments possibly had a long residual effect protecting the plants during their growth by eliminating or greatly reducing bacterial populations. The number of tubers and yield in g/plant were greatest with mancozeb 5 and 1, maneb, 1, and captan 10 g/plant. In the case of maneb and mancozeb at 5 and 10 g/plant the phytotoxicity was evident in reduced numbers and weights of the tubers. The disease severity index was highest and plant yields were low with captan at 1 and 5 gm/plant, and thiram at all three levels.

Field tests

Germination was approximately equal in all treatments, indicating absence of phytotoxic effects (Table 4). Disease severity indices of only maneb and mancozeb were statistically similar to the non-inoculated control and statistically dif-

Table 3. Effect of four fungicides on growth of potato plants inoculated with Pseudomonas solanacearum under greenhouse conditions.[1]

Chemical and dosage (g/plant)	Tuber yield g/plant (no./plant)	Plant height (cm)	Disease index
Captan (1)	36.4[2] b (1.2 gh)	22.0 a	46.7 c
Captan (5)	61.8 b (1.4 fg)	12.4 bc	41.7 e
Captan (10)	138.0 a (4.2 bc)	11.2 bc	0.0 i
Maneb (1)	139.2 a (4.6 a)	17.4 ab	0.0 i
Maneb (5)	39.0 b (2.2 ef)	2.2 ef	16.7 g
Maneb (10)	55.0 b (3.0 de)	2.8 de	0.0 d
Mancozeb(1)	114.8 a (5.0 ab)	15.6 ab	6.7 h
Mancozeb	96.0 ab (5.6 a)	5.6 cd	0.0 i
Mancozeb(10)	58.6 b (3.6 cd)	4.6 cd	0.0 i
Thiram (1)	58.0 b (1.6 fg)	16.8 ab	48.4 b
Thiram (5)	7.2 c (0.4 h)	11.6 bc	45.0 d
Thiram (10)	11.8 b (2.2 f)	9.2 bc	30.0 f
Control	20.4 b (1.2 gh)	21.8 a	73.4 a

[1] After 30 days growth.

[2] Treatments with the same letter are statistically similar at 5% probability.

ferent from the inoculated control. Disease severity indices of captan and thiram were not statistically different from the inoculated control. This contrasts with greenhouse results where they were statistically lower. These differences may be due to field conditions where residual effects are reduced over those of the greenhouse. The low severity indexes of these two products could be due to the bactericidal effect, or to by products with bactericidal effects which had more persistance in the soil. Residual effects of some pesticides were directly proportional to their initial concentration (Munnecke and Mickail, 1967). In these instances the dosages were high. Another possibility is that some antagonistic organisms to P. solaneacerum were stimulated.

Maneb was the only treatment (r=0.02) with the rates of infection statistically smaller than the inoculated control (r=0.07) (Figure 1). The treatments that had the highest rates of infection were Agrimycin 100 (r=0.33) and the inoculated control (r=0.55). Between these two rates there was no significant difference (Figure 1).

The percentage of infected tubers was statistically similar in all treatments and the non-inoculated control (Table 4)

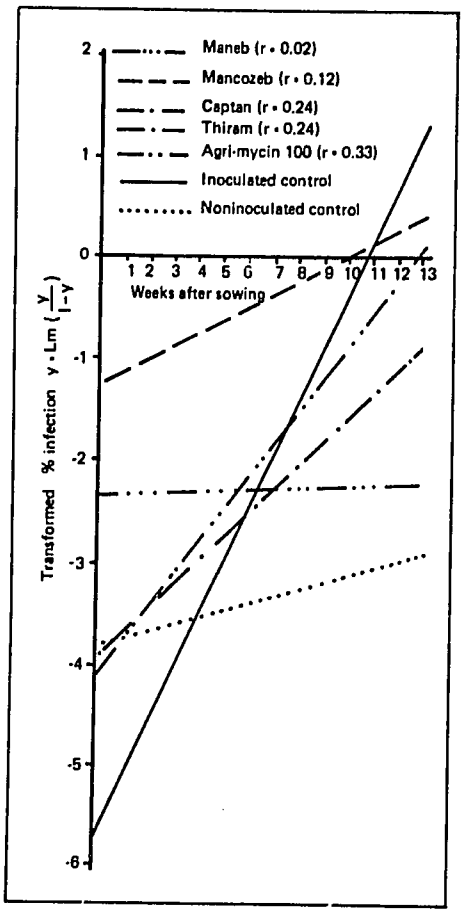

Figure 1. Rates of infection of Pseudomonas solanacearum in plots with application of five different pesticides.

Table 4. Effect of fungicides on potato plants inoculated with Pseudomonas solanacearum.

Fungicide	Germination (%)	Disease index	Plants with symptoms	Infected tubers (%)	Tubers/plant	Yield (g/plant)
Acrimicin 100	87.3 a[1]	29.2 a	56.4 a	90.0 a	4.9 bc	197.4 bc
Captan	84.0 a	17.5 ab	35.2 b	72.5 a	5.1 bc	143.2 bc
Maneb	86.3 a	7.7 bc	15.0 cd	70.0 a	3.4 c	85.6 c
Mancozeb	82.3 a	6.0 c	13.5 cd	75.0 a	6.5 b	244.4 b
Thiram	90.8 a	18.0 ab	32.6 bc	80.0 a	2.9 c	87.1 c
Inoculated control	86.5 a	28.4 a	56.1 a	78.8 a	4.6 bc	188.3 bc
Noninoculated control	92.8 a	3.4 c	7.2 d	40.0 a	13.8 a	570.6 a

[1] Treatments within each column with the same letter are statistically similar at 5% probability.

suggesting that the soil borne inoculum obscurred treatment effects. Only the non-inoculated control produced stastically more tubers per plant and higher yields than did the inoculated control, Agramicin 100, captan, and mancozeb. Maneb and thiram were lowest in yield. Possibly due to phytotoxicity, the coefficient of correlation between disease severity index and yield was - 0.44 suggesting that disease had considerable effect on yield.

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METHODS FOR EXPLOITATION OF GENOTYPES ADAPTED TO HOT-DRY CLIMATES

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A method was developed for the exploitation of heat tolerant potato genotypes. Botanical seed were planted and grown in a glass chamber under temperatures of 30 ± 3°C (day) and 20 ± 2°C (night). Daylength was 13 hours and supplementary lighting was provided by fluorescent lamps. After about 100 days, 9.1% of the seedlings had small tubers. Similar results with seedlings were obtained under natural daylength and temperatures only when they were grown during the summer.

Some of the clones which proved to be heat tolerant in repeated tests, were grown in the field with two control cultivars. The clones had higher tuber yields per plant than those of the heat-sensitive cv. 'Up-to-Date', and some clones outyielded the heat-tolerant cv. 'Desiree'. This method for assessment of heat tolerance is sug-

gested as a helpful tool for breeding cultivars better adapted to hot climates. Its advantages, as compared with screening in the field, are: a) results of a test under controlled conditions are more reliable; b) it can be conducted throughout the year; c) clones can be protected from infection by disease and viruses especially in hot climates, where high aphid populations are common during most of the year.

Methods for the assessment of drought tolerance under controlled conditions are investigated.

HEAT AND DROUGHT TOLERANCE OF POTATO GROWN IN HOT-DRY CLIMATES

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The response of six potato cultivars to water stress under high ambient temperatures was investigated. Osmotic adjustment was observed in leaves of all six cultivars, being the highest in 'Spunta' and the lowest in 'Troubadour'. Concomitantly, 'Spunta' maintained the highest turgor potential under water stress conditions, while 'Troubadour' had the lowest values, indicating the relationship between the degrees of osmotic adjustment and turgor maintenance. The lowest diffusive leaf resistance under water stress conditions was exhibited by 'Desiree', while 'Up-to-Date' had the highest values both in stressed and non-stressed plants. In addition, 'Up-to-Date' had a larger root system than 'Desiree'.

The effect of repeated short periods of water stress during a hot season on six potato cultivars was investigated. The number of tubers per plant tended to decrease in response to water stress in the cultivars 'Desiree', 'Alpha', 'Elvira', while in the cultivars 'Up-to-Date', 'Spunta' and 'Troubadour' which had less tubers per unstressed plant, no consistent effect of water stress on tuber number per plant was observed. However, tuber yield per plant was reduced due to water stress in all cultivars tested.

No consistent effect of water stress on the percent of misshapen and sprouting tubers was observed, indicating the marked effect of the high temperatures on these traits. 'Up-to-Date' and 'Troubadour' had the highest percentage of sprouting tubers while 'Alpha' had the lowest.

Differences in accumulation of dry matter in tuber tissue were observed, and the lowest decrease in dry matter content in response to water stress was obtained in 'Alpha'. It is interesting to point out that the greatest decrease in the osmotic potential of the tuber (the more negative values) were also found in 'Alpha' tubers.

In view of these results 'osmotic adjustment' of the tuber tissue (possibly associated with the capacity to accumulate dry matter in the tubers under water stress conditions), as well as tolerance to tuber sprouting in response to high temperatures, are suggested as possible criteria for evaluation of cultivars for adaptation to water stress and high temperatures.

BREEDING FOR EXTRA-EARLY POTATO CULTIVAR NEA 303 BY MEANS OF SELECTING CLONES WITH EARLY TUBERIZATION

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Although the relationship between physiological earliness of potato and early profitable tuber yield is rather close, inheritance of these characters is not controlled by the same genetic system. It is important to note that neither physiologically early or late varieties differ significantly in ability to produce a profitable yield early in the growing season. In other words, not all physiologically early varieties produce an early profitable tuber yield. An objective to release extra-early varieties which are provided with both physiological earliness and early profitable tuber yield is proposed.

Results suggest that ability to produce a profitable yield early, is dependent on a number of factors, such as date of initial tuber formation, number of tubers per plant, rate of tuberization (tuber growth per week) and rate at which potato plants make early top growth. According to the above factors of yield mentioned, the following breeding scheme was used:

The superior clones with physiological earliness were selected in first and second clonal generations.
From the 3rd clonal generations, the superior clones with early profitable tuber yield among a large number of physiologically early clones were selected by means of sampling the hills at intervals of one week from the middle of bud stage, counting the number of tubers per plant, and the rate of tuber growth week.

Finally, a new extra-early potato cultivar NEA 303 which is provided with the following characteristics has been released in 1980:

Extra-earliness and production of early profitable yield is caused by the combined effects of early tuber formation, larger numbers of tubers per plant and, greatly increased rate at which potato plants make early top growth. Consequently, the output of cultivar NEA 303 reached a new level, 20 tons/ha., significantly higher than the standard cultivar Ke-xin N°4, when both were harvested on July 20th in Harbin, Heilongjiang province of China. The growing season from emergence to harvest covered about 45-50 days.

In the southern region of China, seed potatoes of common cultivars degenerate rapidly because of virus diseases.

The early development of "mature-plant resistance" in NEA 303 to virus infection combined with early harvesting of the crop are useful in producing tubers for seed. NEA 303 is highly resistant to PVA, PVX, PVY, and is slightly infected with PLRV.

HEAT ADAPTABILITY OF THE POTATO

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Summary

The capability of the potato to adjust to physiological responses due to the change in environmental temperature is genetically controlled. The difference in physiological adjustments among cultivars is believed to be primarily in the adaptability to high temperature rather than in the genetically fixed heat tolerance. This adaptive character which protects plants from heat stress for a better performance works only if the heat adaptability can occur quickly so that heat damage does not occur. Cultivars are not so easily differentially separable in heat adaptability unless the plants have been subjected to a temperatural regime above 30°C for about 12-24 hours.

Introduction

Heat stress is one of the major environmental factors influencing the adaptation and productivity of crops such as the potato, especially when temperature extremes coincide with critical stages of plant development. Most crop plants will not tolerate long term exposure to temperature above 35°C. This is primarily because the maximum rate of photosynthesis in crop plants is about 20 to 30°C, while the rate of respiration tends to increase with rising temperature up to the point at which injury to the cells begins to occur. As a result, plants suffer from excessive usage of the photosynthate in respiration. This type of chronic heat stress which can occur in the lowland tropics usually results in decreased yield, but rarely in death. Where heat stress occurs, it is important that cultivars possess a high degree of heat adaptability to survive the stress period.

There is evidence that high night-temperatures enhanced markedly more reduction in yield than high day-temperature (Ofir, et al., 1980).

Results and Discussion

DTO-33 from CIP and Red Pontiac, a local cultivar, were selected for this study because DTO-33 cultivar differing in heat sensitivity from the tuberosum potatoes has been reported based on yield under high temperature conditions (Mendoza and Estrada, 1979).

Heat tolerance in leaf tissues of the potato is a function of acclimating temperatures. At temperatures below 30°C, no significant difference in heat tolerance exists between cultivars tested. The temperature at which cultivars showed the greatest heat tolerant difference is about 35°C. After 24 hours exposure to 35°C, DTO-33 could survive a 50°C treatment for 240 minutes from a non-stress level of 70 minutes, while Red Pontiac for about 150 minutes from 50 minutes (Table 1). Increased heat tolerance can be detected immediately after exposure, and reaches a plateau at about 24 hours. Continuous high temperature is needed for plants to retain high level of induced tolerance.

Table 1. The heat adaptability in leaf tissues of the potato as related to the yield performance under high temperature conditions.

Cultivars	Heat killing time (min) at 50°C		
	Control[1/]	Acclimated[2/]	Yield Performance
Red Pontiac	50	150	Low
DTO-33	70	240	High[3/]

1/ 20/15°C, day/night, 14 hr light.

2/ 35/35°C, 14 hr light, 24 hr exposure.

3/ See reference (Mendoza and Estrada, 1979).

Alexandrov (1964) has suggested that plant cells begin to respond by increasing heat tolerance when the temperature reaches the injurious zone and that heat acclimation is a specific reaction of the cells toward the injurious action of the heat. This appears applicable to the potato which does not significantly change heat tolerance in temperature range from 20 to 30°C. Heat tolerance, however, increased dramatically once above 30°C and the differences in heat adaptability between cultivars became clear. However, when temperature increased above a certain point, i.e. 37.5°C for DTO-33, the acclimating effect declined. Plant age does not influence the pre-acclimation level of heat tolerance but it does affect the heat adaptability (Chen et al., 1982).

Results indicate that differences in performance among cultivars under high temperature condition are more closely related to heat adaptability than the pre-acclimation level of heat tolerance (Table 1). This is also true in the tomato, soybean and common bean (Chen et al., 1982). It is suggested that when breeding for better performance in high temperature environments, perhaps, one should select those progenies which possess high heat adaptability. This character, however, cannot be distinguished among progenies unless plants are subjected to a temperature regime above 30°C for about 12-24 hours.

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EFFECT OF MERISTEM SIZE ON ERADICATION OF POTATO SPINDLE TUBER VIROID

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Summary

Previous experiments have shown that it is possible to eradicate PSTV from infected plants by incubation at low temperature followed by excision of the apical dome of the meristem.

An experiment was carried out to determine effect of meristem size on eradication from an infected clone. Tubers kept at 5-6°C for 3 months were planted and grown at 10°C for 6 months and 3 types of meristems were excised: shoot tips, meristem tips, and apical domes. The effect of meristem size was that 2/24, 8/49 and 12/22 of the plantlets derived from shoot tips, meristem tips, and apical domes respectively were PSTV-free. Similar meristem types excised from plants grown at 22-25°C in the greenhouse uniformly developed PSTV infected plants.

Introduction

Eradication of viroids from infected plants by heat treatment and meristem culture has been unsuccessful or only with low efficiency (Stace-Smith and Mellor, 1970).

The dependence of potato spindle tuber viroid (PSTV) on high temperatures for its replication (Sänger and Ramm, 1975; Lizárraga et al., 1980) allowed Lizárraga et al., (1980) to eradicate PSTV from infected potato plants by growing them from tubers or plantlets in vitro at low temperature (6-8°C). With this procedure 53% of plantlets derived from apical domes of PSTV-infected in vitro plantlets were free of PSTV whereas only 30% PSTV-free plants were obtained from those grown from tubers at 8°C.

To induce growth of small meristematic tissue, enriched medium has to be used which leads to callus formation. From this, plants can be regenerated. However, this procedure may lead to genetic variation (D'Amato, 1975). To avoid genetic variability in plantlets derived from callus, eradication of PSTV was studied by excising 2 meristem types: meristem tip (MT) consisting of apical dome plus 2 leaf primordia, and shoot tips (ST) which includes the meristem tip plus two leaflets. These were compared to apical dome (AD) of meristems (Figure 1).

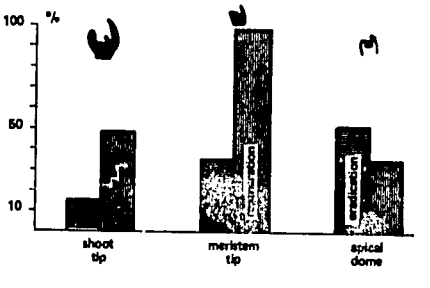

Figure 1. Effect of explant size and source on eradication of PSTV. Drawings at top indicate relative size and shape of explants.

Material and methods

CIP's clone 378704 (Solanum tuberosum) infected with a severe strain of PSTV was used throughout the studies. Twenty tubers kept at 4°C for 3 months were planted in pots and grown in a growth chamber at 10°C, 16 hours daylength and 1500 lux. Twenty PSTV-infected tubers from the same lot were grown to plants under greenhouse conditions at 22-25°C for 4 months as controls.

One hundred AD and 50 of each MT and ST were excised from low temperature-treated plants and controls.

AD were cultivated and grown to calli in medium N°6 of Kao and Michayluk (1975) containing 0.8% agar. Calli were transferred to medium MS 13 of Behnke (1975) to produce plantlets. MT and ST were cultivated on Murashige and Skoog's basal medium (1965) containing 3% sucrose and 0.25 mg/l gibberellic acid (GA_3) solidified with 0.6% agar. Plantlets developed from all treatments were propagated in vitro, using a liquid medium (Roca et al., 1978).

Testing for PSTV was done directly on plantlets by a modified procedure of Pfannenstiel et al., (1980). Samples giving negative results in electrophoresis were inoculated to tomatoes and infection was assessed by development of albinism (Yang and Hooker, 1977) and by electrophoresis of inoculated tomatoes.

Results and discussion

Two of 24 plantlets developed from ST, 8 of 49 from MT and 12 of 22 AD were free of PSTV. Therefore, efficiency of eradication was 8.3%, 16.3% and 54.5% for ST, MT and AD, respectively (Figure 1). Regeneration of plantlets from the 3 meristem types was 48% (24/50), 98% (49/50) and 22% (22/100) for ST, MT and AD, respectively. The low percentage of regeneration of ST was due to contamination of cultures with bacteria.

All plantlets developed from ST, MT or AD from greenhouse grown plants at 22-25°C were infected. These results clearly indicate that the smaller the meristem, the higher the frequency of eradication of PSTV is obtained. These possibilities were suggested by Lizárraga et al., (1980) and Stace-Smith and Mellor (1970). Stace-Smith and Mellor (1970) found that plants from which a severe strain of PSTV was eliminated were, however, infected by a mild-strain. In our studies the bioassay on tomato followed by electrophoresis indicated that mild strains are not carried in PSTV-freed plantlets.

Although the efficiency of using meristem tips (MT) for PSTV eradication is lower than that of AD, it is the best choice to free valuable germplasm to avoid possible genetic changes in the genotypes. Furthermore, plantlets can be easily regenerated from meristem tips.

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MILD AND SEVERE MOISTURE STRESS ON POTATOES

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Water conservation is of primary importance in production of potatoes. Drought in 1976 and 1977 and the ensuing uncertainty of the water supply in the western United States has shown that irrigators need to budget their moisture application for effective crop production. Potatoes are very sensitive to moisture stress during certain growth stages, and it is desired to better define these moisture stress relationships in order to optimize irrigation management with reduced water supply.

Knowledge on the effect of moisture stress during various stages of growth is necessary for effective use of limited water supplies. The effect of moisture stress on tuber quality was also documented because of the obvious importance and quality to commercial potato processors. Finally, several varieties have been released recently that exhibit superior quality when subjected to drought conditions. Moisture-stress tolerance of these new varieties allows irrigators in drought-prone areas the option of selecting a cultivar that exhibits high drought resistance.

The overall objective of the project reported herein was to investigate the effects of mild and severe moisture stress at different growth stages on the yield and quality of various potato cultivars.

Procedures

A randomized-block replicated experiment was designed to test the effect of mild and severe moisture stress on the yield and quality of several potato varieties, including Russet Burbank, Lemhi Russet, Butte, and Nooksack. Russet Burbank, Lemhi Russet, and Butte were tested during the first year (1980) and Russet Burbank, Lemhi Russet and Nooksack were tested during the second year (1981). Two moisture stress treatments were imposed on plots grown at Aberdeen, Idaho, a location with a 105 day frost free growing season. The mild moisture stress involved withholding moisture until 10 days beyond the theoretical wilting point at the growth stages of tuber initiation, tuber bulking and maturity. These occur in late June, late July, and mid-August at Aberdeen.

The severe moisture-stress treatment involved withholding the moisture for 15 days past the theoretical wilting point at the same three stages of growth listed above. During both years the potatoes were planted during the first week in May. Six replicates of each treatment were planted.

The potatoes were supplied water through a trickle irrigation system during both years of the experiment. During the first year Chapin™ twin wall tubing was placed approximately 4 inches below the seedpiece in each plot row. During the second year the tubing was placed aboveground between the rows. Moisture levels were monitored gravimetrically just prior to, and 24 hrs. after irrigation. Irrigations were scheduled using a pan evaporation method developed by McMaster during the early 70's. Moisture levels were maintained between 60 and 100% of the available soil moisture (16.5 to 21% on a dry weight basis).

The soil on which the plots were grown is a Declo silt loam with a bulk density of 1.35 and a water holding capacity of approximately 2 inches/ft. Frost was allowed to kill the vines in early September during both years and harvest took place near the 1st of October. Tubers from each plot were graded to determine: (1) total yield, (2) yield of U.S. N° 1's, (3) malformed and knobby tubers and (4) specific gravity. A french-fry evaluation for sugar buildup during storage and subsequent fry color was undertaken during 1980. The results were analyzed with the Statistical Analysis System™.

Results

Because of the space limitation, only the 1981 results are presented in this report (Table 1). The data shows how each variable was affected for a given variety by the various stress treatments.

Severe moisture stress had a much more significant effect on the total yield and yield N° 1's than did the mild stress. Yield and quality were adversely affected by the severe early and middle season stress, but for the Lemhi and Nooksack varieties, the effect on quality was less severe in the early part of the season

Table 1. Potato varietal response to moisture stress treatments.

Total yield	Mild[1/]-early	Mild-middle	Mild-late	Severe-early	Severe-middle	Severe-late	Check
Lemhi	330^{AB}_{a}	305^{ABC}_{b}	336^{AB}_{c}	296^{BC}_{e}	245^{C}_{g}	280^{BC}_{h}	362^{A}_{k}
R. Burbank	288^{D}_{a}	264^{DE}_{b}	298^{D}_{d}	244^{E}_{f}	231^{E}_{g}	259^{DE}_{h}	293^{D}_{k}
Nooksack	296^{FG}_{a}	308^{F}_{b}	322^{F}_{cd}	325^{F}_{c}	249^{H}_{g}	268^{GH}_{h}	317^{F}_{k}
Yield # 1's							
Lemhi	190^{AB}_{a}	195^{AB}_{c}	217^{A}_{f}	159^{BC}_{h}	135^{C}_{m}	164^{BC}_{p}	221^{A}_{g}
R. Burbank	121^{E}_{b}	129^{DE}_{d}	158^{D}_{g}	66^{F}_{k}	100^{E}_{n}	124^{E}_{p}	157^{D}_{r}
Nooksack	196^{HK}_{a}	212^{HK}_{c}	256^{G}_{e}	184^{K}_{h}	174^{K}_{l}	209^{HK}_{o}	229^{GH}_{q}
Specific gravity							
Lemhi	1.090^{A}_{b}	1.094^{A}_{d}	1.093^{A}_{f}	1.091^{A}_{k}	1.081^{B}_{n}	1.093^{A}_{p}	1.090^{A}_{s}
R. Burbank	1.079^{DE}_{c}	1.084^{CDE}_{d}	1.095^{CD}_{g}	1.078^{E}_{l}	1.080^{CD}_{n}	1.087^{C}_{q}	1.083^{CDE}_{t}
Nooksack	1.097^{GHK}_{a}	1.095^{HK}_{d}	1.100^{FG}_{e}	1.099^{FGH}_{h}	1.094^{K}_{m}	1.101^{F}_{o}	1.099^{FGH}_{r}

[1/] Mild and severe treatments are 10 and 15 days beyond theoretical wilting point respectively. Early, middle and late treatments correspond to the growth stages of tuber initiation, bulking, and maturity.

[2/] Effects of moisture stress treatments are compared vertically for each given variety indicated by capital letters. Varietal responses to given moisture treatments are compared horizontally with lower case letters. Treatments with the same letter are not significantly different at the 5% level.

than in the middle part of the season. This was not true however, with the Russet Burbank, which exhibited a severe quality reduction due to severe early moisture stress. The previous year's results also sustain the fact that the yield of US N° 1's is reduced on Russet Burbank with both the mild and severe early stress treatment, more so than the middle stress treatment, which was more damaging to the total yield. This data suggests that the mild late season stress improved the yield of N° 1's of the Russet Burbank and Nooksack, but not of Lemhi. There was also a trend for higher specific gravities when water was withheld during the latter part of the season.

Table 1 also compares varietal performance under given moisture treatments, (the significance is read vertically in lower case letters). This data shows that both the Lemhi and the Nooksack performed better than the Russet Burbank under most of the stress treatments shown. Specifically, the Nooksack significantly out-performed both the Lemhi Russet and Russet Burbank in quality (measured by the yield of N° 1's and specific gravity). In other trials carried out by the USDA, Nooksack did not have higher yield than Russet Burbank and Lemhi. The reason for this difference is the lateness of emergence of the Nooksack, and the fact that in 1981 a severe frost occurred on June 14 which set back the Russet Burbank and Lemhi considerably more than the Nooksack, which had just emerged.

In conclusion, the data presented herein indicate clearly that both yield and quality are adversely affected by drought occurring in the early and middle parts of the season, corresponding to the stages of growth of tuber initiation and bulking. Also, varieties other than Russet Burbank have been shown to produce a higher quality crop under stress conditions (both in terms of frost damage and moisture stress).

USING PRESSURIZED IRRIGATION SYSTEMS TO APPLY POTATO INSECTICIDES

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Fertilizers have been applied to crops through sprinkler systems for a number of years, but only recently have herbicides, fungicides and insecticides been tested for injection through irrigation systems. Injecting agricultural chemicals can be economically advantageous in many cases.

Equipment

In general, an injection system consists of a chemical tank, a single or dual injector pump, a metering device and various couplings, hoses, and an electrical hookup.

The heart of the injection system is generally a positive displacement piston pump that will discharge at the same volume flow rate regardless of the pressure in the sprinkler system. These are simple pumps that take very little maintenance and should function well for long periods of time. There are, however, some check valves in the end of the pump that must be maintained clean and free of debris for the pump to operate properly. To do this, a strainer can be installed up-stream of the pump in the intake line.

In addition to the injection pump system, a check valve is required in the irrigation mainline upstream from the injection point so that if the water is shut off when the injector is operating, any material in the line will not flow back down into the well. The injection pump should also be wired so that if the irrigation pump shuts off during the injection, the injector pump will also shut off. This is necessary to prevent a high concentration of chemical from accumulating in the mainline, which could severely damage the crop when the pump is restarted.

Chemicals

When considering injection of a material, the chemical used should be checked for solubility in water. Wettable powder (WP) formulations can be somewhat difficult to dissolve in the agitation tank; Straight liquids (L) and emulsifiable concentrates (EC) are more desirable. Agitation is generally desirable in the supply tank if emulsifiable concentrates or wettable powders are used. Another thing to check is the pH of the makeup water in the agitation tank. If the pH is greater than 8, an acid should be added. In some cases high pH water can reduce the effectiveness of the chemical.

In general herbicides and insecticides are available in various formulation and chemical types but the time of injection is governed more by the method of chemical activity than the class of material. Does the material need to be left on the leaves and insects when the injection is finished? If that is the case, the injection should be done as close to the end of the set as possible. In the case of the center pivot, the pivot should be sped up to make a revolution as quickly as possible, so that the material is carried by a small amount of water and remains mostly on the leaves. If, on the other hand, a material that acts within the soil is desired (in other words, systemic insecticides or soil active herbicides), it may be necessary to wash the material down into the soil profile for adequate efficacy. To accomplish this, the material should be followed by an application of more water to wash it into the soil. It may be desirable to make the application 2-3 hours prior to the end of the set to ensure that the materials are washed down only a short distance. In the case of a center pivot, two possibilities exist. Either the pivot can be slowed down to give a higher water application or the material can be applied in a rapid application and then the pivot can be run around another time at a slower speed to wash the material down (if the chemical is not too volatile).

Mixing

When the injection is taking place, it is necessary for the chemical to mix adequately with the irrigation water from the point of injection in the mainline before it reaches any branches so that uniformity throughout the field is maintained. What this means is that the injection point should be located more than 10 pipe diameters upstream of any branches. Even though the flow in sprinkler systems is generally turbulent because of the high velocity of water in the pipes, it still takes about 10 pipe diameters for adequate mixing to occur so that the irrigation water and chemical mixture is ready for branching. Mixing can be an especially serious problem in wheel-line systems because the distance between the pump and the T where the system branches to the two legs of the mainline is generally quite short, and adequate mixing cannot be accomplished in this short section. In this case, it may be better to inject downstream of the T in each branch of the mainline.

It is important to make sure that adequate coverage is achieved with the material. Several things can enhance the chances of a good effective control using sprinkler systems to apply chemicals. The first is to inject when the wind speeds are relatively low. In general, injections should not take place with any non-moving system (such as wheel line, hand line or solid-set) if the wind speed is in excess of 6-8 mph. Because pivots are moving, the allowable wind speed can be approximately doubled to 12-15 mph and still have adequate uniform application. Another good practice is the use of dye to mark the presence of the chemical in the system. It is very important to be certain that the chemical is clear from the lines to make sure that adequate coverage is accomplished. Mixing a pint of fluorescent dye into the agitation tank at the time of injection will effectively mark the progress of the chemical through the irrigation system and indicate when it is time to shut off. This becomes slightly more complicated with center pivots because the chemical will start out the line and trace out a spiral sweep. The easiest way to

Table 1. Efficiency of solid set sprinkler system for control of the Colorado potato beetle.

Formulation, rate[1] and year of test	Date of pre-treatment[2]		
1980	July 11	July 12	July 14
Imidan 50W[4]	32 a[3]	0 a	0 a
Sevin SL [4]	83 a	1 a	1 a
Lorsban 4E[4]	71 a	65 b	42 b
Check	83 a	95 b	64 b
1981	July 14	July 19	July 23
Vydate 2L 1 lb	109.5 A[4]	0.0 A	1.5 A
Guthion	186.0 A	0.0 A	0.0 A
Lorsban 4E 1 lb	185.5 A	161.8 C	147.8 B
Lorsban 4E 1 lb + oil	74.5 A	24.5 B	61.0 B
Check	107.5 A	54.3 B	72.5 B

[1] Rate of application 1 lb/a.

[2] Figures indicate number of beetles per 40 ft. of row.

[3] Treatment means with the same lower case letter are not significantly different from each other using Duncan's MRT at the .05 level.

[4] Treatment means flanked by the same capital letter are not significantly different from each other using Duncan's MRT at the .01 level.

ensure that the entire circle is covered is to mark the point when the injection was started at the outer tower, and then mark the point when the dye reaches the outer tower. This will be several minutes from the time the injection was started, and consequently quite a few feet around the circle from the starting point. When the pivot has made the full revolution to the point where the injection was first begun, the injector pump should be shut off. The pivot and the water should remain on, though, until the outer tower advances to the point where the dye first showed at the outer tower at which time the system should clear of dye and the entire circle should have been covered with no overlap at the beginning or end.

Efficacy

Several chemicals were applied through a solid-set sprinkler system for control of Colorado Potato Beetles during 1980 and 1981 (Table 1). Imidan, Sevin, Vydate and Guthion all provided excellent efficacy when applied by this method.

BACTERIAL DISEASES OF POTATOES IN BRAZIL: PRESENT AND FUTURE TRENDS IN RESEARCH

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Bacterial wilt, caused by Pseudomonas solanacearum, is the main disease of seed potato in Brazil. Because of its zero tolerance in the Brazilian certification law, approximately 10% (more than all the other causes together) of the fields are rejected every year. It shows the importance of this disease on our need of importation of about 9,000 t of seed potatoes per year, especially from Europe.

Pseudomonas solanacearum is native to most of the Brazilian soils, and many areas that should be free of the disease are already contaminated through infected seed lots. Certified seed producers grow potatoes only once in the same area, what contributes to make cost of production very high. Disease control through crop rotation is very difficult because of the large number of weeds or cultivated species that can harbor the bacterium.

According to our survey during the 1979-81 period, races 1 and 3 (represented by biovars I and II, respectively) occur in the main potato producing areas, biovar II being prevalent in the southern and biovar I in the northern half (Table 1). The main cultivar grown in Brazil, 'Bintje', is extremely susceptible to the disease making losses even bigger, although preventing, to some extent, dispersal of the disease through latent infections in the seed. Besides the lack of good source of resistance on wild and cultivated species, and a high population of root knot nematodes in the soil, which may break resistance, the high variability of the pathogen also makes breeding for disease resistance a very hard task. In this regard, potato genotypes from our breeding program and clones from CIP are periodically tested in a uniform, naturally infested field at the National Center for Vegetable Research

Table 1. Distribution of Pseudomonas solanacearum biovars, isolated from potatoes, per state of Brazil.

State	Biovar (s)
Distrito Federal	I and II
Espírito Santo	II
Goiás	I and II
Minas Gerais	II
Paraná	II
Rio Grande do Sul	I and II
Santa Catarina	I and II
Sao Paulo	I and II
Total : 70 isolates	
Biovar I : 20 isolates	
Biovar II : 50 isolates	

(CNPH). Although the level of infestation was not quantitatively evaluated, we have consistently isolated only biovar I in this field. Results of our last trial with some of CIP's material are shown in Table 2.

As it can be seen, the German Cultivar Achat was the most resistant among the materials tested. In fact, we included 'Achat' because of our previous field observations, which indicate it as resistant to bacterial wilt. However, this cultivar can be infected symptomlessly, what makes dispersal through latent infection very important.

Campo-bio, caused by Pseudomonas solanacearum, is an interesting disease that has been observed by farmers for a long time, but has never received, until now, attention from researchers. According to some farmers, this is a disease of recently-opened land; in the first planting, losses are very severe, sometimes total, but the land can be replanted with potato without subsequent problems. This contrasts sharply with bacterial wilt, in which case the area cannot be reused with Solanum species for long time. Aerial symptoms are similar, although progress of campo-bio, in the field, is usually faster than bacterial wilt. Tuber symptoms, however, do not share similarities at all. In

Table 2. Percentage of dead plants and average 25, 32, and 40 days after planting of 8 clones and 3 potato cultivars tested under field conditions at the Centro Nacional de Pesquisa de Hortaliças, EMBRAPA, Brasilia, D.F., Brasil.

Clone or cultivar	Days after planting			
	25	32	40	Average
80224	22.8[1/]	32.4	94.7	49.6
800223	7.5	22.5	81.1	37.0
800222	50.0	90.0	100.0	80.0
800927	12.3	42.0	86.0	46.8
800226	12.5	33.9	87.2	44.5
720088	16.2	63.4	100.0	59.9
800435	7.5	49.1	100.0	52.2
103009	18.6	45.7	97.2	53.8
Achat	2.5	17.8	81.9	34.1
Bintje	52.2	90.8	100.0	80.7
Aracy	47.5	88.9	100.0	78.8

[1/] Each reading is the average of the percentages of 4 replications with 10 plants each.

campo-bio, darkening is not restricted to the vessels, and there is not the characteristic exudation of bacterial wilt. Campo-bio symptoms on tubers are also of dry rot, never slimy as for bacterial wilt. Tubers frequently do not show any external discoloration; the inside, however, may be brown or black to a great extent. We have frequently observed tubers with compartmentalization in terms of symptoms; this rarely happens with bacterial wilt, where often the whole vessel ring is infected.

Our data, although limited to one year of field work, have confirmed farmer's observations. Our results strongly suggest that bean (Phaseolus vulgaris) maintains the disease situation as if it were in recently-opened land. Of three cultivars we tested (Bintje, Delta, and Radosa), 'Bintje' was the most susceptible. Land cultivated to different crops, including potato, has shown a great decrease and stability in the disease level. Another interesting and important aspect of campo-bio is that it is limited to certain fields. This has been clearly demonstrated in the Cerrado region of Central Brazil.

In a experiment designed to test the effect of cold (4°C) and ambient (20-26°C) storage temperature on seed tubers (cultivars Bintje, Delta, and Radosa) originated from campo-bio symptomatic or asymptomatic plants, we found a great difference in terms of storage temperature and tuber origin (Table 3).

Biochemical, cultural and color characteristics indicated that this pathogen is similar to P. solanacearum biovars I and II.

Pathogenicity tests have confirmed the virulence of our isolates, as well as campo-bio's symptoms.

Erwinia rots - Soft rots are important in both storage and field. So far, there has been no comprehensive survey to determine damage or species involved. The problem of soft rot is increased because of tuber washing for consumption purpose, especially during the wet season. Characteristic blackleg symptoms are more frequently found on plants from imported seed, which indicates the seed origin of the inoculum.

Table 3. Effect of storage temperature on rot of seed tubers from plants with and without symptoms of campo-bio.

Cultivar	Rotted tubers (%)	
	In cold storage	At ambient storage
Without symptoms		
Bintje	3	14
Delta	11	11
Radosa	2	18
Average	5.3	14.3
With symptoms		
Bintje	18	60
Delta	54	60
Radosa	25	67
Average	32.3	62.3

Future needs

Considering the importance of potatoes and their bacterial diseases to Brazil, we believe that research in the two most important potato producing states, Parana and Rio Grande do Sul, is imperative. The problem of land reutilization for seed potato production must be studied with emphasis.

We believe that integrated control through the use of resistance, cultural practices, and choice of land will be the only possibility, at the present time, for bacterial wilt control of both seed and consumption potatoes.

Finally, we strongly need researchers working in the area of Erwinia rots in order to survey their occurrence and damage and to indicate their control.

BROWN-EYE: A LATE SEASON AND STORAGE DISEASE OF POTATO TUBERS IN BRAZIL

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Cylindrocladium clavatum Hodges and May (1972) was first described associated with roots of pine, araucaria, and eucalyptus in Brazil. In 1979 (Lopez and Mendonça, 1980) it was found infecting potato tubers in three Brazilian states. Symptoms consisted of rounded, superficial, dark brown lesions with well defined margins, up to 1.0 cm in diameter. At that time, lenticels were shown to be the natural site of entry of the fungus. One of our isolates was deposited at the American Type Culture Collection, Maryland, U.S.A., as number ATCC 44649.

The disease caused by C. clavatum on potato was named brown-eye due to the characteristic appearance of the lesions (Figure 1), being prevalent in the wet (Sep-Mar) season. It was noted that Fusarium and Erwinia could cause, under certain conditions, similar symptoms on potato tubers. In fact, C. clavatum could be isolated together with Fusarium sp., in many instances, from the very same lesion.

Artificial inoculations in our laboratory have shown that symptoms can be reproduced in as early as three days, in warm (24-28°C) humid chambers.

So far, brown-eye has been detected in five states - Distrito Federal, Goiás, Mato Grosso do Sul, Minas Gerais, and São Paulo. Although these are not the main potato producing states, they share in common the type of soil/vegetation - Cerrado. C. clavatum was considered to be the most common Cylindrocladium species in Cerrado soils, where it could be isolated from roots of wild and cultivated plants, in either disturbed or undisturbed soil (Almeida and Bolkan, 1981). We have recently found C. clavatum infecting peas, under field conditions, in the Distrito Federal, where generalized necrosis of the pea root system was observed. Isolates from peas were virulent on potato tubers and vice-versa.

Figure 1. Brown-eye symptoms: noninoculated (top), naturally infected (center), and artificially inoculated (bottom) potato tubers.

Initial attempts in our laboratory to control brown-eye consisted of in vitro and in vivo chemical control, as well as an evaluation of seven cultivars - Aracy, Belladonna, Bintje, Edzina, Nicola, Recent, and Santo Amor - in relation to tuber resistance to the disease.

Of the five fungicides tested in vitro, benomyl at 0.5 ppm was considered the best for total inhibition of radial growth; thiabendazole was also effective, but only at 5.0 ppm (Table 1). Captafol at 0.5 ppm inhibited conidial germination in vitro, but benomyl and zineb treatments, at 25.0 ppm, yielded 52 and 11% of germinated conidia, respectively (Table 2).

The in vivo tests indicated benomyl, captafol and thiabendazole as good post-harvest treatments with efficiency decreasing as the time between inoculation and fungicide spray increased (Table 3). Most of the potatoes produced for consumption in Brazil are washed after harvest. Although we lack experimental data, our observations indicate that washing increases brown-eye incidence; technically, we do not recommend washing, but since growers refuse to abandon this technique in order to get better prices, addition of chemicals to washing water could be a simple procedure to control this disease.

Table 1. Effect of fungicides on mycelial growth[1/] of C. clavatum "in vitro".

Fungicide	Concentration (ppm)			
	0.5	1.0	5.0	25.0
benomyl	0[1/]h[2/]	0h	0h	0h
captafol	17cde	15de	10fg	9fg
thiabendazole	13ef	7g	0h	0h
zineb	22ab	22ab	24a	24a
PCNB	21abc	22ab	19bcd	19bcd
check	19bcd			

[1/] Mycelial growth expressed in mm; readings taken four days after inoculation of PDA plates, at 22-24°C.

[2/] Means followed by the same letter do not differ statistically according to Duncan's New Multiple Range Test, at P = .01.

Table 2. Effect of fungicides on conidial germination of C. clavatum in water-agar.

Fungicide	Concentration (ppm)			
	0.5	1.0	5.0	25.0
benomyl	99[1/]a[2/]	86abcd	77cd	52e
captafol	0f	0f	0f	0f
thiabendazole	100a	79bcd	75cd	93abc
zineb	99a	97ab	98a	1f
PCNB	98a	99a	74cd	69d
check	99a			

[1/] Readings taken 10 hr after inoculation, expressed in % germination, at 22-24°C.

[2/] Means followed by the same letter do not differ statistically according to Duncan's New Multiple Range Test, at P = .01.

Table 3. Effect of fungicides on the control of C. clavatum on potato tubers of cv. Achat.

Fungicide[2/]	Treatments[1/]			
	0	24	48	Average[3/]
benomyl	0[4/]	14	33	16c[5/]
captafol	2	1[illegible]	36	17c
thiabendazole	1	18	41	20bc
zineb	26	32	50	36a
PCNB	33	37	46	39a
water check	26	27	39	31ab
average[6/]	15	24	41	

[1/] Number of hours between chemical application after inoculation.

[2/] Fungicides were sprayed at 1000 ppm in water.

[3/] Fungicide averages, in all treatments.

[4/] Average number of lesions.

[5/] Means followed by the same letter do not differ statistically according to Duncan's New Multiple Range Test, at P = .05.

In evaluating resistance of the seven artificially-inoculated cultivars to the disease, using lesion size and number as parameters, no statistically significant difference was found (P = 5%).

We are presently interested in studying pathogen variability and distribution, and chemical and cultural control under field conditions.

Mention of a product does not imply approval or recommendation of the product by the authors or their institution, to the exclusion of other products that may be suitable.

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PRODUCTION OF CERTIFIED POTATO SEED IN COLOMBIA

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The potato is a basic food for the Colombian people. Therefore, its production and distribution have economic, social and political importance. According to the National Planning Department and 1979 data, the potato crop represents 10% of the gross value of total agricultural production, ranking thi after coffee and rice. This crop uses 30% of the chemical fertilizers and 60% of the fungicides used in Colombian agriculture. It is estimated that 90,000 farmers and about a million persons depend economically on this activity. Finally, the potato is a staple focd for low-income consumers, 90% of Colombian families eat potatoes, and 6% of the food budget is spent on potatoes, second after meat.

At present, 160,000 ha are planted to potatoes each year, with 2.2 million tons of production, at the cost of US$2,400 per ha. The commercial colombian potato varieties belong to Solanum tuberosum ssp. andigena (tetraploid) and S. phureja (diploid). On average, 1t/ha of tuber seed is planted.

I. THE GENESIS: CROP BREEDING RESEARCH

Colombian research for potato improvement was started in 1881, under the guidance of Eugene Hamburgin, a British agronomist.

Research aimed to solve agronomic problems such as the control of Phytophthora infestans, manuring, and seed production.

Early potato breeding was developed between 1939-1947 by Manuel Bastidas, an Ecuadorian agronomist, and Manuel A. Navarrete, Colombian geneticist, graduate of Cornell. Both workers used germ plasm from Colombia, Ecuador, Peru and Bolivia with little success. Basically, andigena x andigena hybrids were made as the foundation genetic material, from which the variety Parda Pastusa (44-17: Quincha x Tocana Colorada) was selected.

During 1948-1950, Colombian potato research was thoroughly reorganized and directed by J.G. Hawkes, a British botanist. It was continued by the Colombian Agricultural Program of the Rockefeller Foundation, under the guidance of two United States plant pathologists, Lee E. Heidrick and H.D. Thurston. The most valuable contribution of the Program to the country was training of outstanding graduates in agricultural sciences at the M.S. and Ph.D. levels. At the same time, the Colombian Potato Team was integrated and headed by Nelson Estrada, a Wisconsin graduate. The breeding method changed to tuberosum x andigena hybridization. To date, the Colombian Agricultural Research Institute (ICA) has delivered to growers 25 new potato varieties belonging to S. tuberosum ssp. andigena. These varieties now cover about 90% of the potato acreage.

II. BUILDING THE SEED SUPPLY

In this Andean country, production and supply of certified potato tuber-seed is accomplished in isolated highland zones, above 3,000 m above sea level, at 10°C of medium annual temperature, where scarce aphid populations exist.

Since the beginning of potato research, recommendations were given toward the use of good quality seed. These included the recommendations of Juan de Dios Carrasquilla in 1891 to select seed from vigorous and healthy plants, and that of Rafael Ospina in 1916 in Antioquia, to avoid seed cutting and the exposition of seed-tubers to the air and light.

The first serious commitment to potato seed production was initiated in 1947 in Antioquia, by Carlos Garcés a Colombian plant pathologist graduated of Cornell, with the assistance of H.K. Fernow, Cornell Professor. During 1949 a nation wide seed project was set up. During the Rockefeller Foundation period (1951-1966), the potato program and the seed project were advised by John S. Niederhauser, plant pathologist, in charge of the Interamerican Potato Improvement Project.

Recently, from 1978 to 1980, seed production was reactivated by a cooperative project on potato seed improvement, under the responsibility of ICA-CIP, financed by the Ford Foundation and coordinated by the author, also a Cornell graduate. The main objectives of the project were: (1) production of basic seed, (2) development of appropriate technology, and (3) organization of private seed enterprises.

Production of basic seed. Basic seed is produced under the responsibility of ICA. Initially the material was derived from meristem culture supplied by CIP. This was propagated by three cycles before it was sold to registered seed growers. According to the present regulations (Resolución No. 040 de 1981), basic seed should be free from PVX, PVY and PLRV. Disease testing and use of rapid propagation techniques are routinely followed

Profitable technology - Nearly all seed planted comes from sprouted consumption potatoes. The first step was to evaluate the healthiness and yield potential of commercial potatoes grown in the highlands, above 3,000 m above sea level, in comparison with improved official seed. Results showed that official seed, although apparently more healthy, did not yield significantly more than common seed. The average yield experiments in the highland was 35 tons per hectare. Actually, Colombian potato growers neglect the health of seed and spend more money on fertilization, (about 30% of the total cost), to secure a relatively profitable crop, (Table 1). In another season and location, at 3,200 m above sea level, using basic seed and compound fertilizer (10-30-10), the following results were obtained (Table 2).

These foregoing figures are a brief indication of the yield potential of the potato crop, under short day and normal environmental conditions.

Table 1. Effect of fertilization on yield and visual symptoms of virus infection of two commercial varieties.

Fertilizer (10-30-10) (T/H)	Parda Pastusa		ICA Purace	
	Virosis (%)	Yield (T/H)	Virosis (%)	Yield (T/H)
0.5	41	11.1	27	7.0
1.0	19	13.2	16	11.4
1.5	1	22.5	9	19.5

Table 2. Yield of two commercial varieties planted with basic seed in the Colombian highlands.

Distance between plants (cms)	ICA Purace yield (T/H)	Parda Pastusa	
		Fertilizer (T/H)	Yield (T/H)
30	54.1	1.5	53.6
40	52.0	2.0	60.0

Note: The variety ICA Purace was planted with 1.5 tons of fertilizer per hectare, and Parda Pastusa was planted at 40 cms. between plants on the row.

Planting potatoes with a double row system was successfully tested and re-evaluated at two Agricultural Colleges. It is well known that the period over which foliage remains productive is much influenced by environment, temperature, light, water supply, and nutrition. Besides fulfilling these physiological requirements of the plant, it is necessary to find a cropping system which will allow efficient use of land, field equipment, soil moisture and labor. In 1976 in Tibaitatá the double row system yielded 40 t/ha compared with 30 t/ha for the conventional single row method. At present, the double row system is being advantageously applied in seed production, under dry conditions as well as in soils with deficient drainage, because the potato root is sensitive to the lack of moisture and very sensitive to the excess of moisture. In both planting systems much research remains to be done on size of tuber-seed, planting distances, fertilizer dosages and their interactions for each variety and locality.

Encouraging the organization of private seed enterprises. Active cooperation with

Table 3. Private potato seed enterprises, date of registration, and personnel in Colombia.

Potato Seed Enterprise	Date of Registration	Technical Assistant
Caja de Crédito Agrario	6-12-68	Germán Torres
Bernardo Herrera Valenzuela	18-09-80	Agrónomos Asociados
AGRO CEBEG LTDA.	27-11-80	Bernardo Correa
Enrique Triviño Galeano	27-11-80	Enrique Triviño
Semillas de Papa Ltda. SEPAL	13- 1-81	Lauro Luján

Colombian Potato Growers Federation (FEDEPAPA, founded in October 18 of 1974), and training courses have facilitated organization of four small private potato seed enterprises, besides the Agrarian Bank. All of them are registered by ICA, (Table 3).

The above listed enterprises produced and distributed 2,000 tons of good quality seed in 1981. Early demonstration trials with certified potato seed at 2,600 m above sea level, doubled yields in Cundinamarca and tripled yields in Boyacá, in comparison with a common seed.

The future and evolution of the Colombian Potato Seed Project, developed over 30 years, will depend largely on the technical and economic capacity and honesty of the active seed Enterprises, as well as the interaction of environmental factors and virus vectors in the seed production areas.

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INTERNAL FACTORS INFLUENCING BACTERIAL SOFT ROT IN POTATO TUBERS

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Summary

The development of bacterial soft rot caused by Erwinia carovotora may be enhanced in potato tubers by decreasing concentrations of oxygen and calcium, and maintaining high water potentials and membrane integrity. The influence of levels of reducing sugars, phenolics and oxidative enzymes on bacterial growth in tuber tissue has not been clearly defined as yet. When either Erwinia suspensions or sterile pectolytic enzyme preparations are injected into whole tubers prior to aerobic incubation, lesion restriction occurs well in advance of the synthesis of stress-metabolites, such as phytoalexins, suberin deposition, and wound cork formation. These observations and other research findings indicate that resistance under ambient oxygen levels mainly reflects interference with the action of cell-wall degrading enzymes.

Introduction

Considerable losses during storage and in transit caused by bacterial soft rot of potato tubers occur on a worldwide basis. The resistance of potato tubers to infection by soft rot bacteria in the post-harvest period is greatly influenced by a number of internal factors (Table 1). These include levels of oxygen, reducing sugars, calcium, and phenolics; status of membranes; and water potential (Lund, 1979; Perombelon and Kelman, 1980).

Oxygen level in the tuber has been shown to have a major effect on development of bacterial soft rot by Erwinia carotovora (De Boer and Kelman, 1978). Tests for bacterial soft rot potential are now completed under conditions in which availability of oxygen to the tuber is limited (Lund and Kelman, 1977). The apparent increase in resistance as the concentration of ambient oxygen increases may reflect either a change in the physiological conditions in the tuber tissue or an alteration in the ability of the bacterium to grow and spread in the host tissue.

Results and discussion

In recent studies in our laboratory, cell-free culture supernatants containing pectolytic enzymes of E. carovotora were injected in whole tubers that were then incubated under low oxigen levels. At the injection sites soft rot lesions were induced similar to those observed in tubers inoculated with viable cells of Erwinia and incubated anaerobically. In contrast, no decay lesions were elicited under aerobic conditions when similar injections of either purified enzymes or bacterial cells were made. The failure of pectic enzyme preparations to macerate tissue in whole tubers under aerobic conditions indicates either that pectolytic enzymes are inactivated under aerobic conditions in vivo, or that pectic substrates are not accesible (Maher and Kelman, 1982).

Table 1. Internal factors that may increase bacterial soft rot in potato tubers.

Factor	Proposed mechanism
Low oxygen	Inhibition of wound-healing and defense reactions
High levels of reducing sugars	Enhanced bacterial growth
Increase in membrane permeability	Enhanced bacterial growth due to leafkage of nutrients
High water potential	Injury to cells by pectic enzymes increased by high turgor
Low calcium	Enhanced maceration of cell walls by pectic enzymes
Low levels of phenolics	Reduced toxicity to bacteria due to decreased levels of oxidized phenolics

Inhibition of wound-healing responses under anaerobic conditions has been considered responsible for the increased susceptibility of potato tubers to bacterial soft rot under low oxygen (Wigginton, 1974). Among processes that are oxygen dependent are: 1) suberin formation, 2) production of rishitin and other phytoalexins, and 3) accumulation of oxidixed phenolics.

A number of investigators have concluded that suberin serves as a barrier to the spread of bacterial growth and the action of the pectolytic enzymes (Fox et al., 1972). However, the resistant response in tubers under aerobic conditions following inoculation with suspensions of E. carotovora is observed well in advance of the deposition of suberin which occurs 5-6 days following wounding (Kolattukudy, 1981).

Resistance in potato to Erwinia carotovora has been considered to reflect inhibition of the bacterium by phytoalexins (Lyon, 1978). However, duplication of the disease process with sterile culture filtrates injected in whole tubers under anaerobic conditions but not under aerobic conditions indicates that the primary resistance mechanism must be directed towards the macerating enzyme rather than the bacterium per se. In addition, the time frame for development of inhibitory concentrations of rishitin and other phytoalexins indicates significant levels would not be present at the time localization of infection under aerobic conditions has occurred.

Presence of high levels of phenolic compounds and high phenoloxidase activity has been related to resistance in tubers to soft rot bacteria (Tripathi and Verma, 1975). Since injection of sterile culture filtrates in whole tubers induces patterns of soft rot development visually identical to those caused by viable cells of soft rot bacteria, resistance cannot be attributed to a direct effect of the bacterium by toxic quinones. However, oxidized phenolics are capable of polymerizing proteins (Leatham et al., 1980) and may inactivate pectolytic enzymes produced by Erwinia.

Reducing sugar accumulation in aging tubers has been correlated with soft rot susceptibility; high reducing sugar concentrations would presumably enhance multiplication of the soft-rotting Erwinia (Otazu and Secor, 1981). However, in our studies on soft rot susceptibility, tubers from storage with different concentrations of sucrose and reducing sugars but with minimal differences in water potential did not differ significantly in bacterial soft rot potential.

Recent field studies in cooperation with Dr. Paul Fixen (U. W. -Madison, Department of Soil Science) have confirmed laboratory infiltration experiments that indicated a

direct correlation between levels of calcium in tuber periderm tissue and resistance to bacterial soft rot (McGuire et al., 1982). The increase in calcium is considered to interfere with the action of pectolytic enzymes on cell wall components.

Increased membrane permeability in potato tubers stored at 0°C rather than 5°C has been correlated with increased susceptibility to bacterial soft rot (Workman et al., 1976). When tuber disks are removed from tubers that have been incubated anaerobically, the rate of electrolyte leakage is higher than that observed in suspensions prepared from tubers that have been incubated aerobically (Maher and Kelman, unpublished data). In addition, when tubers are injected with Erwinia carotovora subsp. atroseptica at 4-6 sites including to bud end and the stolon end prior to incubation under low oxygen conditions, the bud end consistently had less tissue maceration than other sites on the tuber. Electrolyte leakage was also lower at the bud end of the tuber than at other sites. These observations support prior evidence that increased membrane permeability enhances bacterial soft rot development.

Although early studies have indicated that high water status favors soft rot development, quantitative measurements of water potential in relation to pathogenesis by soft rot bacteria have been lacking. Freshly harvested tubers may have water potentials of -1.0 to -4.0 bars. Following storage, water potentials decrease to -5.0 to -7.0 bars; after prolonged storage these values may decline to -9.0 to -10 bars. When other factors are held constant, tubers with low water potentials are more resistant to bacterial soft rot than those with high water potentials (Kelman et al., 1978). Under conditions of low water potential, potato cells may be less susceptible to the injury associated with tissue maceration by the pectolytic enzymes (Alberghina et al., 1973). In addition, high turgor in potatoes with high water potentials may contribute to increased incidence of shatter bruises during handling.

Additional research is needed to determine how the various internal factors interact to influence resistance to bacterial soft rot. This information will aid in the development of standardized methods for evaluation of resistance not only to bacterial soft rot but to other storage pathogens and also contribute to the improvement of storage management practices.

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REDUCING THE EFFECT OF STRESS DURING THE ESTABLISHMENT AND GROWTH OF POTATOES FROM TRUE SEED IN HOT CLIMATES

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Summary

The combined effect of high temperatures and heavy rainfall during the establishment period of potato seedlings in the field has a marked influence on the later performance of the crop.

Several practices, including shading by associated crops, different mulches, and others, for diminishing the effects of the stress during the transplanting operation have markedly improved vigour, plant survival, and yield in the hot summer season of Lima and San Ramon (Peru).

Results of a series of experiments are reported.

Introduction

Intercropping is by far the predominant system in which most food crops are produced in the tropical zone. In such a system an intensive and efficient utilization of the land area is achieved by growing a wide assortment of crops in variable spatial arrangement and time (Black and Black, 1977; Ruthenberg, 1971; Trenbath, 1971). The most simple version of intercropping is found in the tropical farmyard, where diversity of products for family consumption and intensive labor are the two major characteristics. More evolved and intensive vegetable production in the tropics normally consists of a sequence of relay crops in which the efficiency in utilizing land, radiation, water, and nutrients is maximized (Andrews and Kassam, 1975). In any intercropping system, stress due to high soil temperatures is diminished by the continuous ground cover resulting in a faster crop establishment.

Introducing potatoes to many hot areas of the tropics may represent a source of extra income to the farmer and would greatly contribute to the nutritional output of the existing farming systems.

Potato production from true seed (TPS) seems to have a higher applicability within tropical farming conditions than the traditional potato grown from seed tubers. Many of the limitation of the latter in warm climates, such as seed tuber availability and cost, bulkiness and storage, are obviated by producing potatoes from seedlings. Also, potato seedlings can be grown and transplanted to the field whenever conditions are appropriate.

Survival of transplanted potato seedlings is normally affected by high soil temperatures and lack of moisture. Therefore, shading provided by associated crops may improve potato seedling establishment under stress conditions and increase TPS crop suitability to tropical farming.

Materials and methods

A series of experiments were carried out in CIP's Experimental Stations at San Ramon, a hot-humid mid-elevation tropical location, and in Lima, a coastal desert area, to assess the benefit of shading by other crops in improving potato seedling establishment.

In all experiments, seedlings of the open-pollinated progeny DTO-33 were produced in trays with a seed-bed mix of peat moss and sand (1:1 volume) adequately fertilized, and transplanted to the field 35 or 40 days after sowing.

During the hot summer in Lima and the hot rainy season in San Ramon, one or two rows of potato seedlings were transplanted between rows of 70 day old maize (Zea mays L.) and soybean (Glycine max L.) in Lima, or maize and sunn hemp (Crotalaria juncea L.) in San Ramon. Distance between rows was 0.9 m and were oriented in a North/South direction.

Records of seedling survival were made and new seedlings were replanted as necessary starting 10 days after initial transplanting. The associated crops were kept in the field until potato maturity, except for some additional treatments in the Lima experiment in which the maize plants were removed 30 days after transplanting.

In all the treatments, soil temperatures at 2 or 5 cm and total radiation received at the seedlings level, were measured in each plot during the seedling establishment period three times every day (8, 12 and 16 hours).

Complementary information was obtained from an experiment in San Ramon where potato seedlings were transplanted in between rows of mature maize plants thinned to two levels of light interception, approximatedly 30% or 60%. Those two light interception levels were combined to three relay periods of 10, 25 and 50 days after transplanting.

Results and discussion

Survival of potato seedlings after transplanting was effectively improved by those crops associations whose level of shading caused a considerable reduction in soil temperature (Table 1 and 2). A tall crop such as maize close to maturity and transplanted potato seedlings seem a suitable combination to improve seedling establishment under stress conditions. In both, Lima and San Ramon, a marked reduction of soil temperature was observed when maize was used as the comparison crop to one or two rows of intercropped potatoes.

Table 1. Soil temperature and potato seedling survival when transplanted in single or in two rows between maize or sunn hemp (San Ramon, hot-rainy season).

Crops	Number of potato rows	Soil temp.[1/] (°C)	Survival (%)
Potato-Maize	1	26.0	77.5 a[2/]
Potato-Maize	2	27.3	73.0 a
Potato-Sunn hemp	1	28.2	64.5 a
Potato-Sunn hemp	2	29.7	62.0 a
Potato (Control)		31.2	34.0 b

[1/] Average soil temperature at noon at 5 cm for 15 days after transplanting.

[2/] Values followed by the same letter do not differ significantly (p=0.05).

The duration of the different crop associations had a marked effect on yield (Table 3). In the Lima experiment, a relay period of 30 days for the two rows of potatoes in maize improved seedling survival without significantly affecting yields. Higher light interception by maize (one row of potatoes between maize) for the same 30 days relay period caused a marked yield reduction. When two rows of potatoes were transplanted between rows of soybean, the level of shading was not enough to affect either seedling survival or yield.

When the combination of different relay periods and shading levels were compared to a monocrop of potatoes in San Ramon, seedling survival was considerably improved by all combinations (Table 4). For the average radiation reduction level of 30% even the longest relay period of 50 days did not affect yields. For a larger radiation reduction, the relay period must be considerably smaller. Thus, for the 60% intercepted radiation level of this experiment, only the relay period of 10 days had yields similar to the control.

Table 2. Transmitted radiation, soil temperature and potato seedling survival when transplanted in single or in two rows between maize or soybean (Lima, summer).

Crops	Number of potato rows	Transmitted radiation (%)[1/]	Soil temp. (°C)[2/]	Survival (%)
Potato-Maize	1	44.2	25.5	93.0 a[3/]
Potato-Maize	2	67.0	26.0	85.2 b
Potato-Soybean	1	75.5	28.5	77.7 c
Potato-Soybean	2	85.3	29.0	72.5 c
Potato (Control)		100.0	29.5	76.5 c

[1/] Average of 3 readings during the day, for 10 days after transplanting.

[2/] Average soil temperature at noon at 2 cm for 10 days after transplanting.

[3/] Values followed by the same letter do not differ significantly (p=0.05).

Table 3. Yield of potatoes from TPS when transplanted in single or in two rows between maize rows cut 30 days after transplanting or kept until potato maturity, and soybean (Lima, summer).

Crops	Treatment	Relative yield (%)
Potato-Maize	1 A[1/]	53.6 c[2/]
Potato-Maize	1 B	13.4 e
Potato-Maize	2 A	77.3 ab
Potato-Maize	2 B	32.0 d
Potato-Soybean	1 B	69.1 b
Potato-Soybean	2 B	89.7 a
Potato (Control)		100.0 a

[1/] 1 or 2 indicates the number of rows of potato between maize or soybeans.

A = corn removed 30 days after transplanting potatoes.

B = corn throughout the potato growth period.

[2/] Values followed by the same letter do not differ significantly (p=0.05).

Table 4. Seedling survival and yield of potatoes as a relay crop of maize in rows intercepting 30% and 60% radiation for periods of 10, 25 and 50 days after transplanting (San Ramon, dry season).

Intercepted radiation (%)	Relay period (days)	Survival[1/] (%)	Yield (t/ha)
30	10	78.7 a[2/]	15.5 a[2/]
30	25	82.7 a	13.4 ab
30	50	88.2 a	13.3 ab
60	10	81.7 a	15.5 a
60	25	82.5 a	11.8 b
60	50	85.7 a	12.5 b
Control		66.0 b	15.9 a

[1/] Survival 35 days after transplanting.

[2/] Values followed by the same letter do not differ significantly (p=0.05).

Since the associated crops had completed their growth cycle when potatoes were transplanted no major competition for water or nutrients is assumed. As it has been demonstrated in many crops associations (Enyi, 1973; Trenbath, 1971) and monocrops (Beuerlein and Pendleton, 1971; Johnston et al., 1969; Schmidt and Colville, 1967), most probably the reduced photosynthesis rate at lower canopy levels due to shading was responsible for the yield reductions obtained. The reduced radiation in shaded plots led to earlier senescence of leaves, overextension of stems and lodging, particularly in plots with longer relay periods.

Therefore, potatoes from true seed could benefit from the shade provided by an associated crop in a hot tropical environment. However, a proper combination of both, level of radiation reduction, and the duration of such association, must be considered.

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SEED-BED SUBSTRATES AND NUTRIENT REQUIREMENTS FOR THE PRODUCTION OF POTATO SEEDLINGS

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Summary

Among the factors influencing successful establishment of a potato crop from TPS, the production of vigorous seedlings in a short period of time needs special consideration.

This paper reports results of several experiments using different seed-bed substrates and effect of major nutrients on the production of potato seedlings.

Introduction

When growing potatoes from true seed (TPS), transplanting potato seedlings to the field is a convenient technique for many farming situations. Conditions in which seedlings are produced, such as the structure and fertility of the seed-bed substrate have a large influence at later stages of the crop development. While adequate nutrient content of the seed-bed results in the production of more vigorous seedlings, a proper substrate structure provides for the development of a "root-block" which facilitates field establishment (Accatino and Malagamba, 1982). Different materials for possible use as seed-bed substrates and the fertilizer needs of potato seedlings were investigated.

Materials and methods

To identify suitable seed-bed substrates open-pollinated seed of the potato clone DTO-33 were sown in plastic trays containing different volume proportions of sand and either shredded peat moss or a well decomposed compost made of bean residues, manure and leaf litter. In the sand-peat moss mixes a common rate of fertilizer was utilized in all treatments while in the sand-compost mixes the possible benefit of an additional amount of 0.3% of P using a slow release source of P, rock phosphate was investigated.

The seed was sown in furrows 1.0 cm deep and at 5.0 x 2.0 cm spacing, in the trays within a screenhouse and evaluated 35 and 40 days after sowing. Using a mix of peat moss and sand (1:1 by volume) as a common substrate, the effect of increasing rates from 0 to 200 ppm of N, P_2O_5 and K_2O, respectively, on seedling growth under shade (approximately 50% reduction of full sunlight) or direct sunlight, was evaluated. The sources of N, P and K were ammonium nitrate, superphosphate and potassium chloride, respectively. Foliage and root weight of random samples of 100 seedlings when the best treatment achieved transplant size, i.e. when the 5th leaf was developed, were used for comparison.

For a better definition of the response of potato seedlings to P, complementary experiment with a wide range of P rates was carried out. In this a common rate of 100 ppm of N and K_2O was applied to all treatments, other conditions remaining similar to the previous experiments.

Results and discussion

When 50% or 75% peat moss were used in the peat moss-sand mix, bigger seedlings that achieved transplant size earlier were obtained (Table 1). As larger proportions of peat moss were used more compaction of the seed-bed was noticed and inadequate water distribution and aeration at the rooting zone may have occurred. Lower proportions of peat moss resulted in smaller seedlings, possibly as a consequence of faster drying of the seed-bed and leaching of the applied fertilizer. Best structure for the formation of a "root-block" was observed in the mix for equal parts of both components.

Table 1. Fresh weight of 100 seedlings, 35 days after sowing in different proportions of peat moss and sand.

Percent of Peat moss	Percent of Sand	Weight (g)
100	0	140.3 b[1/]
75	25	196.8 a
50	50	204.5 a
25	75	162.8 b
0	100	35.5 c

1/ Values followed by the same letter do not differ significantly (p=0.05).

Table 2. Fresh weight of 100 seedlings, 40 days after sowing in different proportions of compost and sand.

Percent of Compost[1/]	Percent of Sand	Weight (g)
100	0	249.6 a[2/]
50	50	159.7 b
25	75	95.5 b
0	100	6.7 c

1/ Compost analysis: N:1.3%; P_2O_5 avail.: 30 ppm; K_2O 0.05%; CEC:12 meq/100 g.

2/ Values in the same column followed by the same letter do not differ significantly (p=0.05).

Composts are commonly used for seedling production (Kratky and Mishima, 1981; Lesaint and Brunet, 1977). A well prepared compost must have enough nutrients to support adequate seedling growth prior to transplanting. When mixed with soil, sand or other materials, fertilizer application may be required (Sawhney, 1976). In this experiment, vigorous seedling growth was obtained when the compost was utilized alone. When the compost was mixed with sand, the addition of rock phosphate did not have significant effects on the response and therefore, only main treatment effects are shown in Table 2. Most probably deficiencies of nutrients when the compost is mixed could be covered by fast release fertilizers.

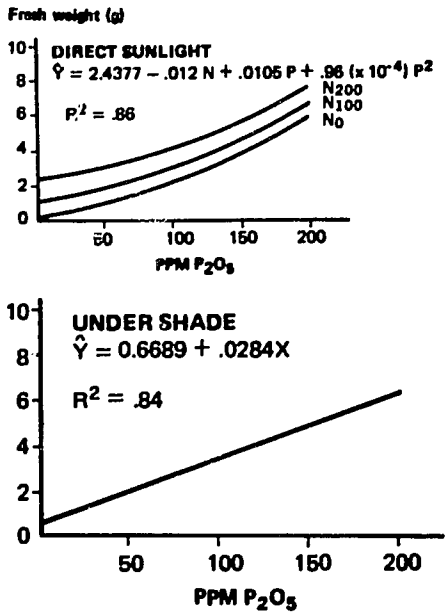

Figure 1. Effect of increasing rates of P_2O_5 on the foliage fresh weight of 10 seedlings 30 days after sowing when grown under shade or exposed to full sunlight.

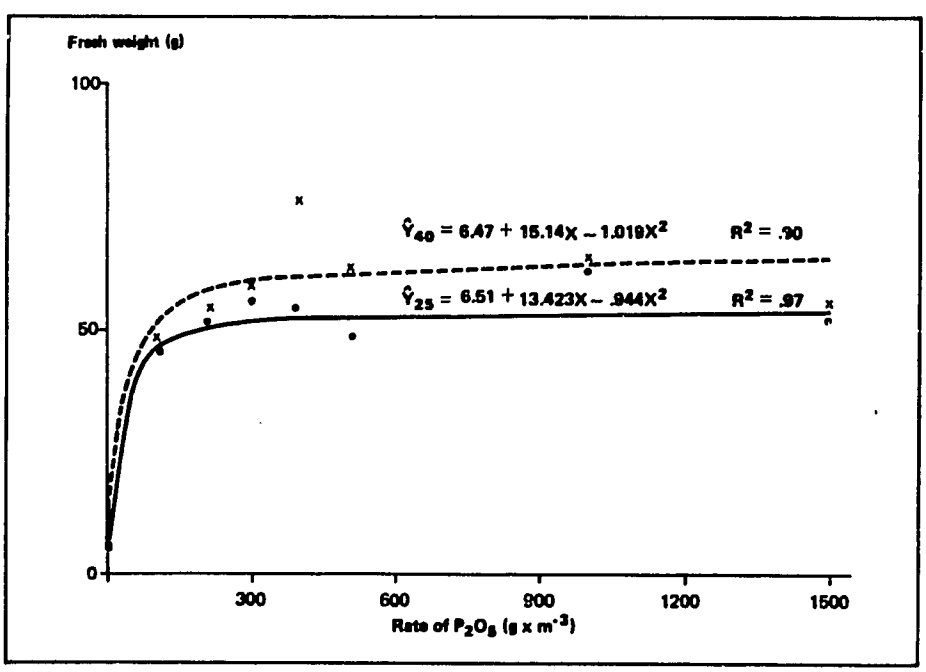

Figure 2. Effect of increasing rates of P_2O_5 on fresh weight of seedlings at 25 days (Y_{25}) and 40 days (Y_{40}) after sowing.

Phosphorus seems to be by far the most important nutrient for early production of vigorous potato seedlings. With the 1:1 peat moss-sand mix, a large response to increasing rates of P was obtained in both shade and direct sunlight. When seedlings were grown exposed to sunlight, increase in rates of both, P and N to a lower extent, promoted seedling growth (Figure 1). Also, at P rates that produced faster seedling growth, N deficiency symptoms particularly at the low N rates were noticeable at the time seedlings reached transplanting size. No significant effect of K was observed.

The optimum level of P_2O_5 according to the fresh weight of seedlings (Figure 2) and observations made on growth uniformity, was between 300 and 400 grams per cubic meter of substrate.

Potato seedlings must be ready for transplanting before a considerable number of tubers start to develop. Tuber formation in growing seedlings seems to be stimulated by sub-optimal conditions. When large numbers of tubers are initiated before transplanting, yield reductions usually occur (Accatino and Malagamba, 1982). Therefore, balanced rates of nutrients in the substrate for producing transplantable seedlings prior to tuber initiation and the use of materials that facilitate formation of a "root block" at transplanting is highly desirable.

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HERITABILITY OF GLANDULAR TRICHOME CHARACTERISTICS IN A SOLANUM TUBEROSUM X SOLANUM BERTHAULTII HYBRID POPULATION

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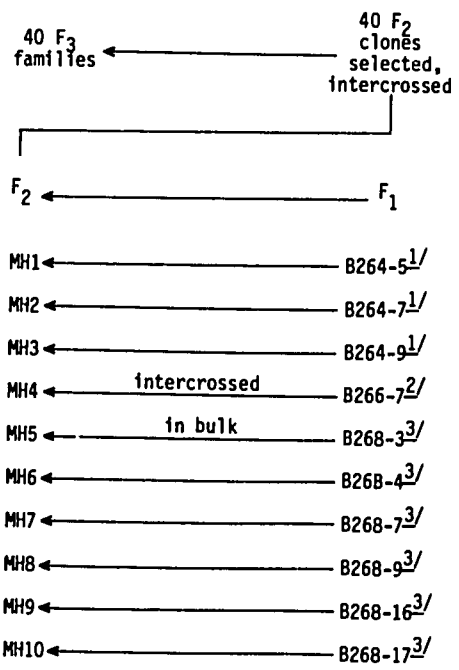
The wild Bolivian potato species Solanum berthaultii (Hawkes) is resistant to several major insect pests of the potato, including the green peach aphid, Myzus persicae (Sulzer), the potato aphid, Microsiphum euphorbiae (Thomas), and the potato leafhopper, Empoasca fabae (Harris). This resistance is due to the glandular trichomes on the leaves and stems of this species. (Gibson and Turner, 1977; Tingey and Gibson, 1978; Tingey et al., 1982). This resistance has been successfully transferred to the tetraploid level by direct hybridization with Tuberosum and Neotuberosum. Clones with high levels of resistance to aphids and leafhoppers have been recovered in the F_2 and F_3 generations.

As part of the International Potato Center's contract with Cornell University, a breeding program has been initiated to transfer the insect resistance of S. berthaultii to useful tetraploid breeding lines. At this stage of the breeding program, genetic information was needed to determine the most effective breeding strategy. A heritability study was initiated at the tetraploid level. The three traits of interest were density of both four-lobed (type A) and simple (type B) trichomes, and droplet size on type B trichomes. Field trials were also conducted to determine the relationship of these trichome characteristics with resistance to aphids. This paper presents the results of our work to date.

Materials and Methods

1) Germplasm

The Tuberosum cultivar 'Hudson' was crossed as a female to three clones of S. berthaultii (see Figure 1). Ten fertile tetraploid F_1s were obtained and were intercrossed in bulk to produce ten F_2 families. Six hundred F_2 seedlings were grown in 3 1/2 inch square pots, examined for the three trichome characteristics, and 40



1/ Parents were Hudson x PI310927-6
2/ Parents were Hudson x PI310927-12
3/ Parents were Hudson x HHC4531c-8

Figure 1. Pedigrees

seedlings were selected at random. The F_2 generation showed a large amount of variation for all three traits. The forty seedlings were intercrossed in bulk to produce 40 families of F_3 seed. The parental F_2s were propagated from stem cuttings and were placed in the field for reexamination of trichome characteristics and evaluation of aphid resistance. Thirty-two seedlings of each F_3 family were grown in styrofoam trays in the greenhouse and their trichomes were examined.

2) Heritability estimation

Regression of F_3 family means on F_2 (parental) values was used to estimate heritability. According to Kempthorne (1957), the estimates obtained are equivalent to the following ratio of variance components:

$$\hat{h}^2 = \frac{\sigma_A^2 + \frac{1}{3}\sigma_D^2}{\sigma_p^2}$$

It is assumed that the random-mating population is at Hardy-Weinberg equilibrium, and that epistasis and linkage are absent. The estimates are most likely inflated to the extent that these assumptions are not met.

3) Trichome density and droplet size measurements

Fully expanded terminal leaflets were excised from seedlings approximately 8 inches tall. The leaflets were then assessed for trichome characteristics by microscopic examination at 64x. The microscope was equipped with grid and micrometer oculars. Trichome data were taken from the center abaxial surface approximately 2 mm from either side of the main vein and between secondary veins. On field-grown plants, the same procedure was applied to fully expanded terminal leaflets. Two counts on each of 25 leaflets were taken on field-grown plants; two counts on one leaflet were used for seedlings.

4) Aphid counts

In 1980, clones were propagated by stem cuttings and were placed in the field in late spring in a randomized complete block design. Four hills per plot and five replications were used. On two dates in late summer, the total number of aphids, Myzus persicae and Microsiphum euphorbiae, were counted on ten lower leaves per plot. The season totals per plot were transformed to a log scale to equalize the variances.

In 1981, the same procedure was used except that four replications were planted and aphids were counted on three dates during the growing season.

Results

Estimates obtained from the heritability study and their standard errors are listed in Table 1. Figures 2-5 display the regression lines of F_3 family means on F_2 parental values. Droplet size on type B trichomes was found to be highly heritable (63.8 ± 7.90% heritability estimate ± standard error). Experience has confirmed that this trait responds very well to selection. Density of type B trichomes had a lower estimated heritability (22.2 ± 4.66%). Another experiment in which heritability was estimated from the response to one cycle of selection for high density of type B trichomes confirmed that heritability of this trait is in the

Table 1. Heritability estimates and standard errors.

Trait	Estimate	Standard error
Type B Droplet Size	63.8%	7.90%
Type B Density	22.2%	4.66%
Type A Density (seedling parents)	17.8%	3.14%
Type A Density (field-grown parents)	31.8%	7.46%

neighborhood of 25%. This trait responds reasonably well to selection when selection is based on counts taken on a single leaf at the seedling stage. Heritability estimates given above were obtained by using the parental values obtained at the seedling stage. Estimates obtained when field counts were used as the parental values were slightly lower.

Density of type A trichomes had a low heritability (17.8 + 3.14%) when seedling counts were used as the parental values, but a higher estimate (31.8 + 7.46%) was obtained when field counts were used. This is believed to be due to the variability of type A density both within and among leaves of the same clone. Type A density is much more variable than the other two traits, and multiple observations are apparently necessary to obtain a reliable estimate of their density. Thus for type A density, larger plants would have to be grown before reliable selection could be practiced. It was found, however, that substantial progress could be made in increasing droplet size and type B

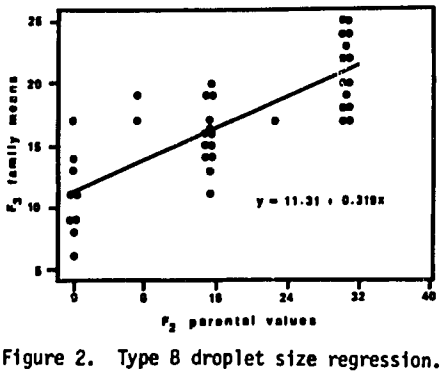


Figure 2. Type B droplet size regression.

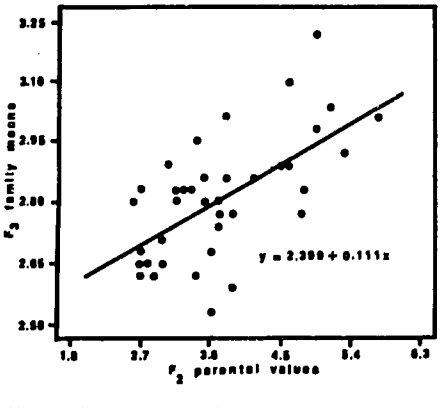


Figure 3. Type B trichome density regression. (Square root transformation).

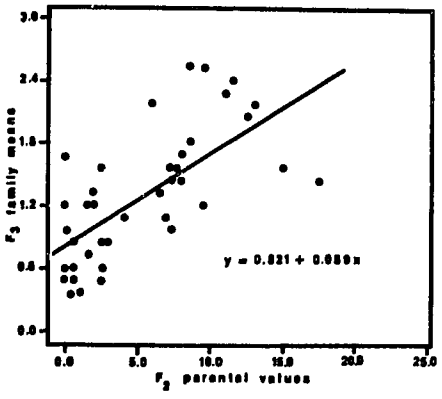


Figure 4. Type A trichome density regression. (Parent values from seedlings).

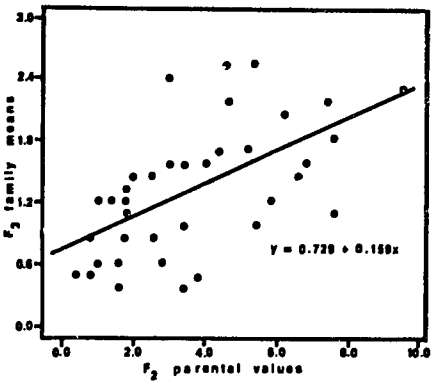


Figure 5. Type A trichome density. (Parent values from field-grown plants).

density if selection were based on the counts obtained on a single fully-expanded terminal leaflet taken when the seedlings were about eight inches tall. This would allow the breeder who is screening for all three traits to first screen seedlings for type B density and droplet size, and then to grow out a greatly reduced number of plants which could then be screened for type A density.

Correlation coefficients of trichome traits with aphid populations are presented (Table 2). All three traits were correlated with aphid numbers in the expected way. Higher trichome density and larger droplet size was related to aphid resistance, but the correlations were quite weak.

Field trials are necessary as an integral part of a breeding program for aphid resistance. In spite of these low correlations, the clones which have demonstrated the highest levels of resistance to aphids in our field trials have had long, dense, type B trichomes with large droplets and chemically active type A trichomes. Possible explanations for the low correlations include simultaneous segregation for many traits, including presence of repellents, feeding deterrents, phenolic substrates, and enzymes (Ryan et al., 1982). It might be possible to avoid field trials in the early segregating generations if trichome density, droplet size, and chemical activity are jointly considered.

Discussion

Tingey and Sinden (1982) reported that accessions of S. berthaultii with both types of trichomes were more resistant than

Table 2. Correlation of aphid populations with trichome characteristics.[1]

Trait	F_2 (MH)	F_3 (D914)	F_3 (D932)[2]
Type B Droplet size	-0.223	+0.004	-0.368
Type B Density[3]	-0.054	-0.471	-0.266
Type A Density	-0.182	-0.142	-0.337
	n=20	n=13	n=15

[1] Season totals of aphid counts were transformed to a logarithmic scale prior to running correlations.

[2] (MH) is a group of F_2 hybrids - the parents used in the heritability studies. D914 and D932 are two F_3 families produced by open-pollination of clones MH5-11 and MH8-62 respectively.

[3] Type B density was transformed to a square root scale.

accessions with only type A trichomes. Tingey and Lauvengayer (1982) emphasized the importance of the interaction of type A and B hairs in resistant clones and accessions. In their study, tarsi coated with type B exudate were highly adhesive and extremely effective in discharging type A trichomes, thus increasing the rate of insect immobilization. Selection for larger droplets and higher densities of both types of trichomes should lead to increased levels of resistance in a hybrid population. But, as noted earlier, field trials to assess the level of aphid resistance are indispensible.

Development of insect-resistant potato cultivars will require a long-term effort. The high heritability of droplet size and intermediate heritabilities of trichome density indicate that these traits will not be extremely difficult to work with. One or preferably two generations of intercrossing with selection for aphid resistance will be required between each backcross to adapted material. An alternative strategy would be to use recurrent selection to jointly improve aphid resistance and tuber appearance once a reasonable level of performance has been achieved. At this time, it appears that good tuber type and good levels of aphid resistance could be combined in a population, 25% of whose germplasm is derived from S. berthaultii. Selection for ability to tuberize in the F_2, F_3, and backcross generations has produced very encouraging results.

In the past few years, the genetic base of our insect-resistant population has been greatly broadened. Genes for resistance to potato viruses X and Y, as well as to the golden nematode, Globodera rostochiensis race A, have already been incorporated into this population. Heat tolerance, resistance to potato leafroll virus, late blight (Phytophthora infestans), and root-knot nematodes (Meloidogyne spp.) are presently being brought into the population. It is hoped that this material and that of other researchers will contribute to the development of insect-resistant potato cultivars by the year 2000.

Acknowledgements

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BREEDING FOR RESISTANCE TO ROOT-KNOT NEMATODE

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Summary

Five cycles of phenotypic recurrent selections for resistance to root-knot nematode Meloidogyne incognita were performed in a diploid potato population formed by both cultivated and wild species of the genus Solanum. The progress made for the first to the fourth cycle was highly significant and increased resistance from 4.5 to 35.5%. Highly resistant clones selected from the fourth cycle have been used in 4x-2x crosses and resistant tetraploids are under testing for yield and other attributes before being utilized by national programs of developing countries. During the development of this work, reciprocal differences were detected, suggesting that the S. sparsipilum cytoplasm has a definite effect in resistance.

Introduction

Root-knot nematodes, Meloidogyne spp., are widespread mainly in habitats when the soil temperature is 20°C or more. Yield losses caused through the damage to the root system along with loss on crop quality due to direct damage to the tubers are the principal effects of these nematodes. A severe attack can reduce yield up to 25%, but if direct damages of tubers is considered, loss in crop return could be higher.

Since the establishment of CIP in 1972, an effort has been made to increase potato productivity in countries of the tropical and subtropical zone. One of the potential limiting factors is the root-knot nematodes by their direct damage to the crop, along with their interaction with bacteria such as Pseudomonas solanacearum. This justified the interaction of a breeding program to incorporate resistance to this nematode.

Results and discussion

The first step was a search of genetic variability for resistance to the root-knot nematodes in the existing Solanum germ plasm. The first group tested for resistance was a sample of 7800 cultivated clones (Table 1).

Table 1. Cultivated germ plasm tested for resistance to M. incognita.

Materials Germ plasm and (no. of clones)	Resistance %	level
Primitive germ plasm (5,865)	1.8	low
Other (750)	1.9	low
Cultivated diploids (1,020)	2.7	low

The frequency of resistant clones and the level of resistance present in the cultivated population was low. Therefore, it was necessary to test the wild tuber bearing species from the genus Solanum (Table 2).

Table 2. Wild Solanum germ plasm tested for resistance to M. incognita.

Germ plasm and (no. tested)	Resistance %	level
Species (65)	40.8	low to very high
Accessions (482)	18.6	low to very high
Genotypes (8,060)	3.5	low to very high

From this group three diploid species (S. sparsipilum, S. chacoense, and S. microdontum) were particularly interesting for their level of resistance and ability to cross with cultivated diploids. These three wild species and the few resistant cultivated diploids were intercrossed to start a recurrent phenotypic selection scheme which after five cycles produced a significant increase in the percentage of resistant genotypes within the population (Table 3).

Immune and highly resistant genotypes from the fourth cycle of recurrent selection were screened for 2n pollen production and crossed via 4x-2x to highly selected heat tolerant early maturing tetraploid cultivars. The resistant tetraploid cultivars obtained are in process of testing for yield and other characterics prior to be distributed to the national potato program with which CIP collaborates.

Table 3. Evolution of the frequency of resistance to Meloidogyne incognita through four cycles of phenotypic recurrent selection.

Year	Selection cycle	No. tested	% Resistance
before 1976	Existing genetic resources both cultivated and wild)	15,695	3.5
1977	1	2,688	4.5
1978	2 and 3	6,482	27.2
1979	3 and 4	11,085	35.5

Crosses of resistant x susceptible produced 38% resistant individuals while the reciprocals only gave 14.5% resistance, suggesting an effect of S. sparsipilum cytoplasm. A study is under way to measure the reciprocal effects and determine the hereditary pattern of the resistance to root-knot nematode.

FACTORS INFLUENCING THE DEVELOPMENT OF THE POTATO AND ITS YIELD UNDER HOT CONDITIONS

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International Potato Center

The range of maturity for genotypes that initiate tubers under hot tropical conditions (International Potato Center, 1980) varies between 60 and 110 days. Experimental results to date seem to indicate that the earlier the clone the lower the yield (Table 1).

Table 1. Yield and maturity of early and late maturing clones in two experiments, Yurimaguas (180 m, 5°S).

Cultivar	Maturity (days)	Yield (t/ha)
LT4	68	7.86
Desiree	75	16.46
LT2	78	13.38
Mariva	100	23.05

At a mid-elevation hot tropical site in San Ramon, Peru, the differences between the harvest dates of early and late clones is not so manifest, although the early cultivars probably mature slightly earlier. Nevertheless the time to tuber initiation is definitely shorter in early clones and yields are markedly reduced (Table 2).

Why should earliness be accompanied by lower yields? Assuming planting date in common for both early and later clones and a similar ability to intercept radiation

Table 2. Tuber initiation, harvest date and yield of various clones in field experiments. San Ramon (800 m, 11°S).

Cultivar	Harvest (days)	Tuber initiation	Yield (t/ha)
DTO 2	81	early	18.34
6947-2	81	intermediate	31.38
LT1	95	early	11.95
Revolución	95	late	26.17
DTO 2	97	early	10.49
Desiree	97	intermediate	27.16

at any point in time, a shorter growing season would obviously restrict the total radiant energy available for conversion to tuber dry matter. Since total and tuber dry matter production are linearly related to intercepted radiation (Allen and Scott, 1980; Bean and Allen, 1981) yields of early clones would tend to be less than those of late clones. Improvement of harvest index and/or efficiency of conversion of intercepted radiation could to some extent compensate for the shorter season of early clones but this has not been our experience.

Early maturity in our experiments at Yurimaguas, besides often being related to early emergence and tuber initiation, was also related to smaller plants with fewer above ground internodes and less leaf area duration, the latter leading to poor light interception. The same was also noted for those clones in Table 2 that initiated tubers early. These characteristics could be typical of either earlier genotypes and/or physiologically old seed (Bean and Allen, 1980). The negative effect of genetic earliness on yield obtained in our experiments may have been overestimated since seed source of genotypes could have influenced the response; the early-maturing clones were multiplied under hotter conditions and therefore were physiologically older than the late clones produced in the cool highlands.

To estimate the effect of seed origin upon the subsequent productivity of seed tubers, a comparison was made in the hot summer of Lima (CIP, 1980), between seed tubers of a late cultivar (Mariva) produced under the hot conditions of Yurimaguas (CIP, 1980) and seed of the same cultivar originating from cool highlands. Seed tubers from both environments were stored in the highlands for the same duration prior to planting. Light interception was considerably less for the crop from the Yurimaguas-produced seed tubers eg. at 37 days after planting 18% vs. 58% for highland seed tuber, as too was the yield (13.4 vs. 19.9 t/ha). Crop duration of the former was also 10 days less. Cool storage conditions can to some extent offset the negative physiological effects of producing seed tuber under hot climates (Wiersema and Booth, 1981).

In addition to the effect of seed tuber source of early clones on their yield in hot climates our experimental results seem to indicate that the bulking rate of clones that initiate tubers early is much lower than later initiating clones. Selections were made in various seedlings families for early, late or no tuber initiation under controlled hot conditions and multiplied once in cool conditions (Sattelmacher, 1981). Results indicate that although at early harvest yields of early initiating clones were greatest, late tuberization was advantageous in terms of final yield. The bulking rate averaged 13.1 g/m^2/day dry matter compared to 2.5 g/m^2/day for early tuberization.

In another experiment where initiation of tubers was delayed by a photoperiod night light-break (NLB), the bulking rates of clones in which initiation was delayed by NLB were considerably greater than those of the control (0.60 vs. 0.36 g/plant/day). Although all the data are not at present available, there are indications that the faster bulking rates associated with later initiation were due to the greater leaf area at tuber initiation, and therefore probably more interception of incident radiation.

Whereas long days can delay tuber initiation, clones adapted to longer than tropical days, when stored in diffuse light under tropical short days, tend to be predisposed to initiate tubers very early under hot conditions. This would be a definite disadvantage for the achievement of potential yields and therefore further experiments are in progress to measure such an effect.

Of the agronomic treatments available for manipulation of potato development most published studies have been made on the influence of nitrogen supply to the plant. High nitrogen supply at planting delays tuber initiation whereas low nitrogen has an opposite effect (Sattelmacher and Marschner, 1979). In our experience, when all nitrogen fertilizer was applied at planting or hilling up, no significant effect was noted upon tuber initiation, nor upon the duration of bulking. Similarly shading of plots (Midmore, et al., 1982) did not alter significantly the maturity of the crop.

Although under field conditions closer spacing hastened tuber initiation, yields were always greater than at wider spacings. This was particularly notable for the smaller statured early clones, which achieved complete crop cover much sooner at higher densities, and intercepted more radiation during the season than wider spaced plants. Closer spacing can therefore compensate for earliness and mean tuber growth rates of close spaced early clones may even exceed those of late clones (Table 3).

Most of the results and discussion have indicated the yield advantage of late cultivars. However, there are certain circumstances when early clones are to be preferred. For example, if the producer requires a quick food supply for himself, then lower yields of early clones may be acceptable, especially if tubers may be harvested from 40 days onward. The lower yielding, early clones may also be preferred if a short growing season is required to allow potatoes to fit into the local cropping system. It is possible to sacrifice duration of the growing season of other crops in order to accommodate a longer season, higher yielding potato (eg. the search for a shorter season rice in the Badulla District of Sri Lanka, to permit a longer season potato (French, Personal communication)).

Table 3. Effects of between plant spacings on tuber growth rate.

Variable	LT4	Desiree
Season length (days)	68	75
Wide spacing (approx. 53 x 10^3 plants ha^{-1})	0.157[1/]	0.174[1/]
Close spacing (approx. 157 x 10^3 plants ha^{-1})	0.335[1/]	0.267[1/]

[1/]Tons per hectare per growing season day.

In summary, based on physiological principles, provided that clones can initiate tubers under high temperatures, and that they do not vary greatly in their efficiency of energy conversion, maximum yield will be achieved by those initiating tubers later. The plants afford a greater leaf area at that time and permit faster and often longer bulking rates than those of smaller plants that initiate tubers and mature very early. Closer spacing in early potato clones can compensate for their lower bulking rates.

A desirable breeding objective would be to combine the quick emergence of early clones with the later tuber initiation, maturity and bigger plant size of late clones in order to intercept more incident radiation during the crop season. Also a further advantage of lateness in a clone is the better compensation than that of early clones for loss of leaf area due to insects or disease (Cranshaw and Radcliffe, 1980). Shorter season clones may, however, escape insect or disease attack and require less chemical control measures.

The practical manipulation of genotype x environment interactions (especially seed tuber production and storage environments) and the search for improved efficiency of conversion of intercepted radiation to dry matter under high temperatures both deserve further study.

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POTATO PRODUCTION UNDER SHADE IN HOT CLIMATES

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Introduction

High air and soil temperatures can severely limit potato production since potato is generally a temperate crop. Often, temperate cultivars growing under such conditions are chlorotic, with a reduced leaf area and poor tuber production. In order to extend potato cultivation to such areas breeding efforts to select clones tolerant to high temperature were started (Mendoza, 1978). A complementary approach is to modify the aerial and edaphic environment to favour growth of potato, and in this respect we herein discuss the use of shade. Artificial shade, e.g. by nets, enables precise regulation of the quality of shade, although its cost may confine it to areas where potato is a high cost food. In contrast shade provided naturally e.g. by companion crops would be less easily regulated but more readily available especially in the tropics and subtropics where intercropping is already a widespread practice.

Previous studies on shade in potato have not considered the benefit in reduction of high temperature for lowland tropical conditions. Continuous dense shade throughout the potato crop cycle reduced tuber yields, whether provided by artificial shades e.g. 34% reduction of full sunlight (Sale, 1976) or intercropping with maize, the potato being planted approximately 3 weeks after maize (Fisher, 1977). Short periods of dense shade applied at the time of tuber initiation or during bulking also reduced yield, but less so than in continuous shade (Sale, 1976).

Either sparse shade spread over the whole potato crop cycle, or a denser shade applied from planting for a short period of time (3-4 weeks) may be effective in reducing soil and air temperatures and conserving soil moisture especially during the emergence period. Various experiments, using both artificial and natural (intercropping with maize and coconuts) shade were therefore conducted during 1980 and 1981 in two tropical sites with environmental conditions as described in Table 1. The experimental results could assist in defining the appropriate timing of shade and the levels of shade to be applied both throughout the day and during the crop cycle.

Table 1. Temperature and rainfall during crop seasons at two sites in Peru.

	San Ramon[1/]		Yurimaguas[2/]
	Drier May-Aug.	Wetter Nov.-Mar.	Drier May-Aug.
Mean max. air t° °C	29.7	29.0	31.4
Mean min. air t° °C	17.3	18.7	19.9
Mean monthly rainfall mm	71.6	235.4	126.4

[1/]Altitude 800 and [2/]180 m respectively.

Results and discussion

Almost all shade treatments, when applied from planting hastened crop emergence except when the companion crop actively competed for limited soil moisture. This effect was equally notable in rainy or dry season plantings and therefore, the reduction in day soil temperature can be assumed as responsible for hastening of emergence. Nevertheless during the dry season an added advantage of shade treatments was the better conservation of soil moisture (Table 2).

Various intensities of shade during the month after planting potato (total daily light transmission varying from 66% to 86% incoming radiant energy) were effected by varying density and planting geometry of a maize crop, planted 30 days before the potato. Although the lowest level of shade reduced the mean daytime soil temperature by an average of 3.2°C and was as effective as that of denser shade in enhancing emergence of the potato crop, maize grain yields were significantly less than those of the dense crop.

The hastening of emergence under shade was most notable with poorly sprouted seed tubers. Similar material planted in unshaded plots in Yurimaguas rotted hence the initial advantage of shade on emergence was largely responsible for the greater yields of the shaded plots. Since maize rows could have differential cooling effects, depending on their orientation, on soil and the emerging potato plants, the effect of a north-south (N/S) or east-west (E/W) planting was studied.

During the wet season in San Ramon shading for 30 days after planting reduced potato yields from 27.6 t/ha in the non-shaded control to 17.7 t/ha in the N/S and 21.1 t/ha in the E/W maize plots. Although emergence was faster in shaded than control plots the extra radiation probably received in the E/W than the N/S plots to some extent helped offset the already low radiation receipts characteristic of the rainy season.

Shading at specific periods throughout the day was effected by inclining permanent shades (25% light transmission) in order to shade plots either during the morning, midday or afternoon. Shading for a short period every morning or afternoon throughout the rainy season increased plant yield relative to the control at San Ramon, whereas a longer midday shade increased yield during the dry season at Yurimaguas.

Table 2. Accumulated soil temperature (5 cm depth) above 20°C, and soil moisture in maize plots of varied spacings. Yurimaguas, 1981.

Maize spacing	Soil temp.[1/]		% Soil moisture 13 days after rain
	Day	Night	
No maize	100	100	12.59
0.7 x 0.7 m	68	97	13.30
1.5 x 0.3 m	79	87	14.47
1.5 x 0.7 m	77	95	13.33

[1/] Expressed as % of accumulated hour degrees above 20°C in no maize plots; day = 153°h, night = 108.4°h.

In the earlier mentioned treatments shade was dense and either applied only during the first month of the potato crop cycle, or throughout the crop cycle but at a particular time each day. In contrast a continuous sparse shade (85% light transmission) was achieved by planting in coconut groves, and although comparisons with conventional controls were not possible, yields during the dry season of the non-irrigated shade plots (14.8 t/ha) were similar to those of a close-by irrigated site (14.9 t/ha) and superior to two other non-irrigated sites (6.6 and 10.3 t/ha). The conservation of soil moisture must have been an important factor in yield improvement, indeed during the cloudy rainy season there was no notable yield increase under shade. On the contrary a greater proportion of tubers, 20% by weight, were rotten at harvest compared to 5% in an adjacent non-shaded field.

The results indicate that shading can modify the environment to the extent that potatoes can be grown in hot climates where excess of soil water is not a problem. Also, intercropped potatoes are expected to have less insect and pest damage, and therefore costly inputs could be reduced compared to a monoculture. Vast area of natural forest, cultivated areas with coconuts, tall fruits crop and intercrop systems with e.g. maize, sorghum, pigeon pea, could be exploited to expand potato cultivation to the hot tropics.

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SCREENING POTATO FOR ALUMINIUM TOLERANCE IN NUTRIENT SOLUTIONS

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Introduction

Although potato is classified as being relatively tolerant to acid soil and aluminium toxicity (Hewitt, 1947) its yield potential is nevertheless markedly reduced on severely acid soils (Lee, 1971) characteristic of the many tropical environment to which potato cultivation is being extended. In order to reduce costly remedial soil application of lime necessary to facilitate cultivation there, various seedling screening techniques to identify more tolerant genotypes are being tested. These techniques have been successfully employed with other crops (Polle, et al., 1978; Hanson and Kamprath, 1979; Konsak et al., 1976).

Materials and methods

Botanical seed of open-pollinated clone DTO-33 was germinated in an incubator at

20°C on moist filter paper and after 10 days uniform seedlings were chosen for further treatment. The base nutrient solution was that suggested by Konsak et al. (1976) upon which various concentrations of $AlCl_3$ were superimposed in order to determine the most appropriate for a differential response of the seedlings to Al. For the first two experiments seedling roots were bathed in Al solutions for five days; root length being measured before and after the treatment period. For the latter (three) experiments the period of bathing in Al solution was one day and staining with hematoxylin (1/2 minute in 0.2% hematoxylin 0.02% $NaIO_3$ solution - scored on scale 0-no stain to 3-black stain) was made after washing the roots in water for four hours. Plantlets from all series of experiments were potted and tuber selections of the surviving plants multiplied once for planting in a replicated experiment using two kilogram pots with an acid soil (pH 4.2, 60% Al saturation of the CEC).

Results and discussion

The increase in root length over the treatment period was markedly influenced by the solution concentration of Al (Figure 1). In both experiments higher Al concentrations reduced root elongation, either in absolute terms or expressed relative to the original root length (data not presented). The mean reduction in root length was 5.4 mm per 1mM increment of aluminium.

Solutions of 0.5 and 1.0 mM Al would appear the most appropriate in which to select for tolerant genotypes, since at higher concentrations all genotypes performed equally poorly.

Data from the first experiment with hematoxylin, in which roots were bathed in water or a 2 mM Al solution, indicated the usefulness of this method in identifying damaged roots. None of the control roots took up the stain whereas those treated ranged from no staining (4%), to very heavy staining (scale 2+3-78%). In ensuing experiments the aluminium concentration was reduced in order to pick a greater number of tolerant genotypes. However, even at the lowest concentration (0.18 mM) 48% were heavily stained.

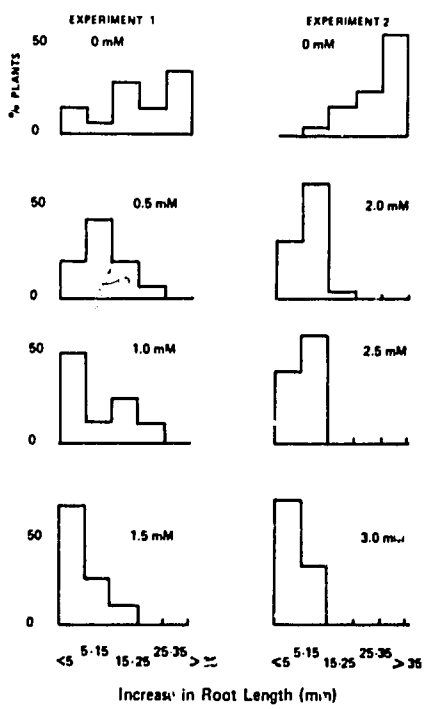

Figure 1. Increase of root length in various concentrations of aluminium over five day growth period.

In another experiment no heavy staining was noted at the 0.05 and 0.10 mM concentrations hence it is suggested that a 0.13 mM solution be optimal for the staining technique. Various botanical seed families are being screened at present to confirm this result.

Subsequent to transplanting a number of the seedlings died, especially those derived from the higher Al concentrations. Those dying may have been extremely susceptible to Al toxicity and their elimination could confer a natural selection pressure. With yield data estimated in the pot experiment the population means of Al treatments will be compared to those of controls to test for any significant shift in Al tolerance. However, to select tolerant individuals by the root length method time consuming plant-by-plant measures have still to be made. On the other hand the staining technique is more rapid, although at the low Al concentrations necessary to descriminate between clones, natural elimination of highly susceptible genotypes will not occur. In our studies plantlets were as uniform as possible, however it has been reported that the hematoxylin stain test is independent of root length (Polle et al., 1978) and would therefore obviate the need to select individuals to uniform root length.

Either of these techniques should prove useful in screening for tolerance of botanical seed populations to Al toxicity, in order that potato production from true seed in acid soils be feasible without lime applications.

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HAPLOID EXTRACTION IN SOLANUM TUBEROSUM

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Introduction

Interspecific crosses have been used as a tool for the production of haploids in different species.

Jorgensen, working with Solanum nigrum, reported in 1928 the first success with the use of interspecific hybridization for haploid detection.

Since 1939 several reports have been written about the results of a systematic search for haploids of the common potato. Hougas and Peloquin (1958) discussed in detail the potential of haploids of the common potato but they pointed out that the first step has been to accumulate a large number of haploids.

The aim of the Braunschweig study is to extract a large number of dihaploids out of the breeding selections of some breeders. These dihaploids can indicate the breeders which characteristics are hidden in their tetraploid genotypes. These dihaploids can also be crossed with wild Solanum species to increase the diversity of potato germ plasm, for instance with respect to resistance to diseases and pests which is of great interest for conventional breeding.

The following report is intended to be a stimulus for discussion. In consequence, there is only a summary of the work in progress, and there is no detailed report of the results in this field which has already been published.

Material and methods

Breeding selections of Solanum tuberosum (2n = 48) were used as seed-parents in the 4x - 2x crosses. Tubers of the seed-parents were planted in the field. Decapitants were collected from the field at the time when the first flowers began to open. They were placed in bottles filled with tap-water in the greenhouse. Every day fresh tap-water was poured into the bottles. The greenhouse was air-conditioned. The temperature was about 15°C at night and 20 - 22° during the day.

Solanum phureja (IvP 35 and 48) was used as pollinator. These pollinators were grown in the greenhouse. Pollen was collected and was either used immediately or was stored after drying over night in capsules placed in a moisture-free vessel and kept at 10°C. The fruits were removed from the decapitants about one month after the last pollination, and were kept at room temperature to mature. The seeds were carefully screened for embryo spot or not. Spotted seeds, spotless seeds, and doubtful cases were counted and kept apart. In the following spring, all spotless seeds and doubtful cases were sown into soil. The seedlings at least gave the data which showed if a plant entered the dihaploid group or not.

Results

Potato dihaploids can be extracted from almost any seed-parent but the results of

the crosses do vary according to the differences of the seed-parents and in the respective years. The observations showed that there have been considerable variations in berry-set between seed-parents and in different years. The data have been summarized in Table 1; although Table 1 gives only a representative selection of the 127 breeding lines used.

Table 1. Comparison of berry-set of different clones in three years.

Clone	Berry-set		
	1979	1980	1981
E 18	1	14	-
E 33	-	15	49
E 43	1	10	-
B 10	-	3	45
B 35	2	14	-
B 56	3	24	3B
S 17	10	6	-
S 38	-	38	33
S 47	2	5	17

Table 2 represents the amount of clones without berries and clones without spotless seeds in three years. Only one seed-parent did not bear a berry at all during three years. It seems as if in 1979 there were better conditions for berry-set than in 1981. This variation was also found by comparing the data of the seeds lacking an embryo spot. But the parents which had seeds without a spot were different during each of the three

Table 2. Amount of clones without berries and clones without spotless seeds in three years.

Clone groups	No berries			No spotless seeds		
	1979	1980	1981	1979	1980	1981
B	2	4	9	4	6	
E	4	3	16	6	7	
S	3	4	11	3	4	
Total	9	11	36	13	17	

years. Compared with the parents without berries the variation of the parents without spotless seeds during the different years was not so strongly marked (Table 2). Perhaps there is not such a great difference between the clones in respect of the ability of the parents to manifest extreme haploid frequency.

The germination rate of the spotless seeds in general was high, in average about 75 - 80%, but few of the spotless seeds had a germination rate of only 18 - 20% per parent. The low rate was independent of the parents because every year other and different clones showed the low rate.

Table 3 summarizes the results of the years 1979 - 1981. The number of spotless seeds in every year seemed to be high but the counted seeds included seeds where the spot marker was not clearly expressed, and also seeds with a stunted embryo. So, in 1979 only 6 plants turned out to be dihaploid. That means that the frequency of haploids was 25 per 100 fruits. In 1980 the spotless seeds resulted in 946 dihaploids. The number of dihaploids which died as seedlings or did not grow up to

Table 3. Summary of haploid frequency.

Solanum phureja IvP 35/48	1979	1980	1981
seed-parent	52	126	127
pollination	831	11,799	18,937
fruit	24	1,502	3,851
seed	149	2,794	13,739
spotless seed	83	1,815	5,838
Haploids	6	946 (482)	
Haploids/ 100 fruits	25	62.9 (32.0)	

plants was very high. So, after removing all these plants out of the group of dihaploids, 4B2 were left to grow up to plants. 70% of these flowered but the number of flowers on the plants varied considerably.

The frequency of haploids relative to the 482 dihaploids was 32 per 100 fruits. The haploid frequency of the two years was 32 per 100 fruits. The average of the seed number per fruit was 1.8. The highest number was 13.3.

In Braunschweig, the dihaploid numbers of the breeding selections are currently being expanded and will be extended during the next years. The next important step included in the programme will be to reach a reasonable degree of fertility in the "raw" haploids, so that the potential of haploids can be fully explored according to the interests of potato improvement.

Summary

Dihaploids were extracted from 127 different Solanum tuberosum breeding lines using Solanum phureja IvP 35 and 48 as pollinators. Up to now 488 dihaploids have been detected. The total frequency of haploids was 32 per 100 fruits, and an average of 1.8 seeds per fruit was obtained. Considerable variations have been found between seed-parents and in the different years and obvious differences exist between the seed-parents within the respective years.

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PROSPECTIVE SYSTEMS AND USERS FOR TRUE POTATO SEED IN DEVELOPING COUNTRIES

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Introduction

Lack of high quality seed tubers is a major factor limiting potato yields and production in developing countries. Developed countries produce and distribute quality seed tubers through elaborate seed certification systems. But in most developing countries these systems either do not exist or do not work efficiently (Monares, 1981). As a result, many farmers must use either costly imported seed or degenerated local seed. Under these conditions, seed tubers constitute a high proportion of total production costs, and both farmer profits and opportunities to introduce better technologies are limited. In addition, use of poor seed tubers results in low yield, high production costs per unit of output, and high potato prices at the consumer level. High farm costs and consumer prices restrict production and consumption of potatoes in developing countries (Van der Zaag and Horton, 1982).

In this context we examined prospective systems and users for true potato seed (TPS) technology. Present knowledge of TPS technology is derived almost exclusively from research under carefully controlled experimental conditions. Socioeconomic study of production and use of TPS in developing countries has only recently begun. Hence, the reader is cautioned that our analysis is preliminary in nature.

The costs of producing, storing, and distributing TPS are expected to be lower than those for seed tubers. Also, use of TPS helps avoid most tuber borne diseases. Hence, this technology would seem to be particularly promising in areas where quality seed tubers and their adequate storage and transport are costly. Since growing a potato crop from TPS is more management and labor intensive than growing a crop from seed tubers, availability of skilled labor may also influence future use of TPS technology.

TPS Systems

Systems for production

True potato seed for commercial use can be either open-pollinated or hybrid (Figure 1).

Production of open-pollinated seeds does not require either special skills nor big investment in land or facilities. It is therefore, a practical alternative open to individual farmers, cooperatives, or national potato programs.

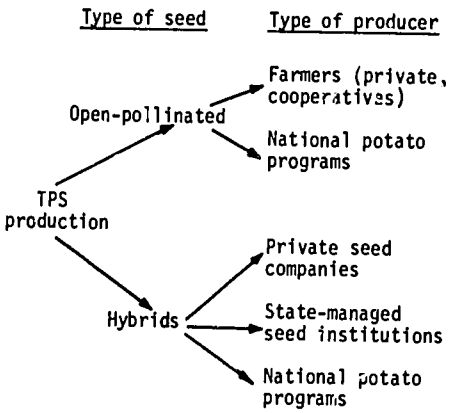

Figure 1. Institutional organization for TPS production.

Production of hybrid TPS is more expensive and technically demanding than production of open-pollinated seed. It does not seem likely that hybrid production of TPS will be economically viable for most developing country farmers, in the near future. Instead, it is likely that hybrid TPS will be produced by seed companies, state-

managed agencies or national potato programs with suitable facilities, skilled personnel and an efficient marketing networks. Research is still needed to improve productivity and lowering production cost of hybrid TPS. Nevertheless, several private companies have already shown interest in commercial production of hybrid TPS.

Systems for producing tubers and seedlings

Direct seed sowing. Several studies, as reviewed by Sadik (1982), indicate that germination, seedling emergence and establishment from directly sown seed may be satisfactory and result in good yield under certain management and growing conditions. With the present state of knowledge, direct sowing may be advantageous in areas where temperatures are moderate, rainfall is well distributed or irrigation is available, and soils are of adequate physical structure. However, the crop may require up to one month more in the field than a crop from seed tuber or transplanted seedlings. As more vigorous early growth is obtained by improved progenies a larger applicability of this systems will be realized.

Transplanting. Use of transplants has been suggested as a practical method for growing potatoes from TPS especially in areas where labor is abundant and farmers are skillful in vegetable production. Its distinctive advantage is that seedlings are established under protected conditions before transplanting to the field (Accatino and Malagamba, 1982). Additional labor is needed to produce, transplant, and care for seedlings. Under stressing environments the additional cost of labor and pesticides necessary for proper care of seedlings may partly offset the reduction in seed cost. It is expected that as farmers learn how to manage the crop and appropriate technologies are developed for these environments, labor, and pesticides requirements will be reduced.

The transplanting system may be most attractive to backyard gardeners and vegetable growers in areas where horticultural skills are found and potato is a high value crop.

Potential uses

Many national potato programs are currently using TPS in limited scale in their breeding programs. It is expected that the use of PTS can be expanded in two additional directions: (a) in the production of basic or foundation seed tubers, (b) to provide hybrid seed to commercial farmers.

Farmers, the main target group of the new technology, can use TPS for three main purposes: (1) production of tubers for consumption, feed or industrial use, (2) production of seed tubers, and (3) production of seedlings for their own use or sale.

Production of tubers for consumption, feed or industrial use. TPS could be used in production of tubers for various purposes, including human consumption, livestock feed, starch and alcohol. Where tubers are produced for human consumption, consumer requirements need to be taken into account, since, in many cases, tuber color, size, form, and composition affect market prices and profitability of potato production. Where consumer requirements are strict, special attention will need to be given to insuring a high degree of tuber uniformity. Where potatoes are produced for livestock feed and or industrial use, insuring uniformity of tubers may be less important.

Production of seed tubers. In this systems TPS is used in the first generation to produce seed tubers. Thereafter, tubers can be used directly for ware production or subjected to further multiplications.

Plants from seed tubers are generally more vigorous than these from TPS. Hence, this method could be most suitable where direct seedling transplant systems are hampered by severe stress from, e.g., diseases, insects, weed and environment. A high rate of seed tuber multiplication can be achieved through production of tubers in direct-seeded beds (Wiersema, 1982). In addition, land and time can be economized by producing tubers from seed in protected areas in the off-season. Preparation and storage of seed tubers requires careful management. For these reasons this system looks more promising in areas where land is scarce, off-season production of first generation seed tubers is possible, and skilled labor is available.

In China a version of this system is used to substitute for the basic or foundation seed tubers generation in a conventional tuber seeds program.

Specialized production of seedlings. In many vegetable growing areas of the world some farmers become specialized in production of seedlings, which they sell to neighboring farmers via a series of market arrangements. It is possible that in the future, potato transplants will be produced and traded in a similar fashion.

Potential areas and users for TPS

Given our present knowledge of TPS technology, we believe that three basic factors will influence farmer adoption of TPS: environmental conditions, quality and cost of available seed tubers, and cost of labor. In our view TPS technology is most likely to be used by farmers where the following conditions are met:

Environment and growing conditions are suitable for potato production.

Quality seed tubers are unavailable or very expensive.

Skilled labor is relatively cheap.

Where potatoes are presently grown, farmers are likely to adopt TPS technology if they find it more profitable than producing potatoes from seed tubers. Use of TPS may allow a substantial reduction in the cost of planting material, its storage, and transportation. On the other hand, labor and pesticides costs may be expected to increase. Where good seed tubers are available yields from TPS may be lower than those obtained from seed tuber. In this case, farmers are likely to accept TPS only if the reduction in total cost is greater than the reduction in total return.

In areas where available seed tubers are of poor quality, use of TPS may result in increased yields. If the output is used as planting material, revenue may be additionally increased because the output price will be higher than that of common seed tubers with higher disease level. In such cases we can expect use of TPS to be highly profitable.

Where potatoes are not presently grown because of the high cost or unavailability of quality seed tubers, TPS may be a promising mechanism for potato introduction into the farming system.

Example. This section illustrates one use of the criteria outlined above for identifying high potential areas for TPS adoption. This example is based on published estimates of potato production costs in a number of localities. These are ranked in terms of their estimated potential for adopting TPS (Table 1). The assumption underlying this ranking is that the likelihood of adoption of TPS technology is greater where the percent net saving in production cost is largest. For simplicity, we assume that TPS has no direct cost and that its use requires 50% more labor than use of conventional seed tubers. All other costs and the yields are assumed to be equal for the two technologies.

Given these assumptions TPS is more likely to be adopted in localities such as A, B and C than F, G or H. This is because in the first group, seed tubers account for a relatively high proportion of total cost and labor for relatively small proportion. Under these conditions percent net savings from use of TPS is significantly higher in the first group of localities than in the second.

Table 1. Localities ranked in potential for adoption of TPS.

Localities	Yield (t/ha)	Production cost	% of production cost Seed (labor)	Net savings US$/ha[1/] (over cost %)
A	7.9	1453	53 (10)	613 (48)
B	20.0	1893	55 (16)	877 (46)
C	12.3	1352	53 (19)	596 (44)
D	18.0	1653	38 (17)	485 (29)
E	9.5	2589	36 (22)	600 (23)
F	20.0	1496	27 (37)	123 (8)
G	18.0	1240	24 (34)	89 (7)
H	7.0	306	38 (62)	22 (7)

1/ Net saving is obtained by deducting additional labor cost from saving in seed (tuber) cost when true potato seed is used instead of seed tuber. The following assumptions were made: (a) true potato seed used as planting material is costless and (b) TPS technology employs 50% more labor than conventional seed tuber technology.

The reader is cautioned to be aware that potential adoption of TPS by farmers will be based not only on the economic relations estimated in this highly simplified example, but also a series of non-quantifiable aspects of local agro-economic conditions.

Conclusion

We expect adoption of TPS technology to occur first in areas where environmental conditions are suitable for potato production, good seed tubers are expensive or not available, and labor is cheap. Adoption is likely to be greatest where the cost of seed tubers represents a high proportion of total cost, seed tuber storage and transportation are problematic, skilled labor is available, and consumers do not have strong preferences for specific tuber characteristics. In areas with extremely low yields caused by very poor seed tuber quality, introduction of TPS may result in marked increases in yields and farm returns, encouraging rapid adoption.

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FACTORS AFFECTING THE NUTRITIONAL QUALITY OF POTATOES

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The Global 2000 Report forcasts that "if present trends continue the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now." As one wit put it, experts have made two projections for life 50 years from now; one optimistic, one pessimistic. The optimistic view is that in 50 years we all will be forced to subsist on crabgrass. The pessimistic projection? There may not be enough crabgrass to go around.

I should like to project that in the year 2000, we shall feed the world a nutritious diet - a diet consisting of many varieties of delicious potatoes. The potato is certainly an important vegetable with regard to nutritive value and extent of cultivation, but the chemical composition can be altered by cultural practices, post-harvest handling, and processing.

Potatoes are grown in many areas of the world and yield a much higher food value per acre than grain. They can be stored easily and are palatable with a high satiety value, that is, gives a feeling of fullness and satisfaction. Even the most inexperienced cook can prepare potatoes easily and quickly, and there are hundreds of recipes for the cook who desires to dress them up. While ambassador to France, Benjamin Franklin attended a banquet where the fare was nothing but potatoes, prepared 20 different ways - no doubt a very nutritious meal.

A study was carried out by McCay at the Animal Nutrition Laboratory at Cornell in which rats were fed for their whole life on a diet comparable to that eaten by one-third the population of U.S. Three-fourths of the calories were provided by either breads or potatoes. The rats fed the diet rich in potatoes had the best survival in old page and the greatest mean span of life.

I. Chemical composition: Nutritive value

It is difficult to obtain a clear picture as to the chemical composition for composition varies with variety, storage, growing season, soil composition and type of fertilizer as well as with the methods of analysis used by different investigators.

An average percentage composition is as follows: water - 80; carbohydrate - 18; protein - 2.0; lipid - 0.1; mineral, vitamins, etc. < 0.1. The high water content should be noted when comparing food values, for when potatoes are compared to dry foods such as rice the impression given is unfair.

Carbohydrate

The constituent of highest concentration other than water is carbohydrate which is comprised largely of starch. Its chief role in nutrition is furnishing calories for energy. One medium sized potato yields approximately 100 calories. Potatoes may have 0.2 - 6 percent sugar, but a high sugar content gives off-flavor.

Protein and nitrogen

28-51 percent of the nitrogen occurs in the form of protein and the remainder is in nitrogenous substances that enhance the protein efficiency. The limiting amino acids are methionine and cystine but milk furnishes these abundantly, so potatoes and milk make a good protein combination.

Lipid

Although the amount of lipid is small, approximately 0.1% on the fresh weight basis, its importance cannot be judged solely by its quantity, for its role in membrane structure makes it a vital part of each cell.

Vitamins

Of the vitamins included in the recommended daily dietary allowances of the National Research Council, potatoes offer substantial amounts of four, namely ascorbic acid (Vitamine C), niacin, thiamin, and riboflavin. Government figures reveal that potatoes contribute more vitamin C to our food supply than any other major food. Potatoes are a nutritionally important source of ascorbic acid. Yet the content of the vitamin varies with variety, maturity, storage conditions, as well as the mineral nutrition applied to the soil in which the tubers are grown.

Minerals

The potato is a good source of iron and magnesium as well as contributing some trace minerals lacking in milk. It is rich in potassium and low in sodium. Fortunately for those attempting to reduce their blood pressure by limiting salt intake, the potato is an ideal food.

II. Quality factors

However, nutritive value is only one of the quality factors of food to be considered. A food may have high nutritive value but unless it is acceptable and eaten, its nutritive value is of no importance. Other quality factors include color, flavor, texture, and freedom from toxic substances. Since there is insufficient time to discuss all of these, we shall consider only the first two.

The color of food is important, for food is often rejected because of "off" color. Black potatoes are unacceptable. The three main types of potato discoloration are nonenzymatic (Maillard), after-cooking blackening and enzymatic darkening. Let us consider the latter in some detail. Enzymatic darkening results from the reaction of phenols with oxygen in the presence of polyphenol oxidase to form quinones which then polymerize to form the black pigment, melanin. For several years we have studied the factors involved with this type of blackening. Darkening is highly correlated with the phenolic content, and several factors such as variety, types of fertilizer, storage conditions, etc. have been shown to influence phenolic content. Potato lipids, although small in quantity are important in cell structure and are correlated with tuber discoloration. The flavor of potatoes is also important. Studies have shown that bitterness and astringency are associated with the phenolic and glycoalkalid content of tubers.

III. Factors affecting tuber quality

A. Effect of fertilization

Fertilization of potaoes is commonly done to maximize yield and economic return, yet inappropriate levels of applications may result in undesirable effects.

Boron:

Boron-foliar spray on potato plants applied at the time of tuberization reduced significantly the phenolic content and enzymatic darkening and increased the ascorbic acid content of tubers.

Magnesium:

In a two years study, magnesium sulfate was applied at rates of 0, 20, 40, and 100 lb/acre. Tubers receiving 40 lbs/acre Mg SO_4 discolored significantly less, were significantly lower in total phenolic content, and were significantly higher in crude lipid and phospholipid content than the controls.

Nitrogen:

Ammonium nitrate was applied at rates of 100, 150, 200 and 250 lb/acre. Enzymatic darkening and phenolic and ascorbic acid contents increased significantly as the level of nitrogen increased.

Phosphorus:

Phosphorus in the form of mono ammonium phosphate was applied at rate of 0, 50,

100 and 150 lb/acre. Ascorbic acid, total nitrogen, protein, and non-protein content were significantly increased and the phospholipid content significantly reduced by phosphorus application.

Potassium:
Two kinds of potash fertilizer, potassium chloride and potassium sulfate, were applied at different levels to the soil in which potatoes were grown. Phenolic content and enzymatic darkening were decreased significantly by both forms of potassium, but the chloride was more effective in reducing darkening and phenolic content.

Zinc:
Zinc sulfate was banded in the soil at the time of planting at rates of 0, 20, 40 and 100 lb/acre. Zinc fertilization significantly reduced phenolic content and discoloration of tubers. Nonprotein nitrogen and free amino acid contents were reduced at all levels of zinc application, and total nitrogen was significantly reduced at the 100 lb/acre level.

B. Mechanical injury
Postharvest change in potatoes is a major problem that results in considerable loss of edible produce each year. Losses occur in both quantity and quality. Physical factors such as rough handling during harvesting, grading and packaging which result in mechanical bruising or cut injuries are responsible for a large share of these losses. Frequently bruised tissue is not visible until the tuber is peeled. Results from our laboratory showed that both the crude lipid and phospholipid content of both bruised and wounded tissue was significantly lower than the controls and that the lipid content of potatoes is one of the determining factors in the susceptibility of tubers to darkening.

C. Viral infections
Tubers from each of the four varieties that were infected with PVX were compared to those that were free of the infection. Enzymatic darkening and phenolic content were significantly higher and lipid content lower in virus-infected than in virus-free tissue. The increased susceptibility to enzymatic darkening is probably due to alteration of lipid and phenolic metabolism following infection. Infection with PVX resulted in a decrease in Ca, Fe, and Cu and an increase in P and Zn as compared with the controls.

D. Effect of maturity and storage
Ascorbic acid content of tubers varied with variety, maturity, and storage time and temperature.

Summary

The potato is an ideal food for the year 2000. Tuber quality is very important, and since quality can be controlled somewhat by cultural practices, postharvest handling and processing, much research is needed in these areas.

A METHOD FOR SCREENING POTATOES FOR RESISTANCE TO GLOBODERA SPP. UNDER LABORATORY CONDITIONS

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Introduction

A method for rearing cyst-nematodes on plants grown in a medium of water-agar in petri dishes was used to screen potatoes for resistance to potato cyst nematodes under laboratory conditions. This method has previously been used to study the biology of nematodes, sex determination and species hybridization (Mugniery, 1978, 1979).

Material and methods

Small pieces of tubers with sprout were cut and placed in Petri dish containing 2% water-agar. Plates were kept in the dark and at room temperature (ca. 20°C). Root growth was initiated after four days. Individual roots were inoculated by placing three or five freshly hatched larvae directly on the root near the root tip. Penetration occurs immediately.

Twelve days after inoculation it is possible to observe young L_4 females. Adult females protruding from roots can be counted 30 days after inoculation. The susceptibility or resistance of the potato tested is determined by the ratio of total number of developed females upon the total number of inoculated larvae.

However, as sex is environmentally determined, any detrimental factor will affect the nematode development (Mugniery and Fayet, 1981). Thus, the number of larvae inoculated per root must be carefully evaluated, because resistance of plants can be over estimated if too many larvae are inoculated (Table 1). On the other hand, if root diameter is 500 µm or more, the number of larvae per root must be not more than five. On the contrary, with thin roots, competition is very high (Ross and Trudgill, 1969; Mugniery and Fayet, 1981), the number of inoculated larvae must be reduced to three.

Results and discussion

Results of resistance tests with C.I.P. clones inoculated with a french population of G. pallida Pa 3 from Kermat (France) are shown in Table 2. Some clones showed a good partial resistance with a ratio of 17% or less. None showed total resistance as it was found with G. rostochiensis (Table 1).

However, these results obtained may not be related with field results because the hatching factor of the plant is not measured. Previous tests have shown that Solanum melongena is very susceptible in Petri dish, exactly as S. tuberosum or Lycopersicum spp., but not under greenhouse conditions. Reason is that S. melongena does not induce hatch of the larvae. In Petri dish conditions, this factor is omitted because freshly hatched larvae are used. Furthermore, in Petri dish, two cultivars of potatoes may express the same susceptibility but in field conditions rate of multiplication may be different. This is the case with the cultivars Roseval and Sirtema which have the same susceptibility but the former multiply field population more than the latter (Mugniery 1976). Reason is that the early potato Sirtema has a smaller quantity of roots than the mid-late potato Roseval and the number of loci of penetration is reduced.

These restrictions mean that the Petri dish method might be well adapted to screen genetic resistance of potatoes in a breeding program. Meanwhile, it is necessary to check the field resistance with more advanced clones.

Table. 1. Influence of inoculum density on the observed resistance to G. rostochiensis R01.

Potato cultivar	Total larvae inoculated	Females developed (no.)	Ratio (%)
9-203-1			
5 larvae/root	95	55	58
10 larvae/root	220	96	44
9-212-1			
5 larvae/root	105	61	58
10 larvae/root	130	49	38
Prosna			
5 larvae/root	100	52	52
10 larvae/root	200	75	38
Astarte			
5 larvae/root	115	20	17
10 larvae/root	180	10	6
Ukama			
5 larvae/root	150	0	0
10 larvae/root	170	0	0

1/ Ratio: (Number of female developed/ total larvae inoculated) x 100.

Table 2. Resistance and susceptibility of selected CIP clones to a french population of Globodera pallida (Pa3).

Clones	Number of larvae inoculated	Number of female developed	Ratio (%)
276. 034.1	150	19	13
275. 196.12	225	30	13
275. 131.22	189	26	14
278. 107.3	139	23	17
278. 103.7	253	46	18
275. 186.1	153	34	22
275. 129.75	208	49	24
276. 008.16	169	65	39
275. 131.28	161	72	45
275. 175.22	123	69	56

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SCREENING FOR VERTICILLIUM TOLERANCE BY THE USE OF TOXIC METABOLITES PRODUCED BY THE PATHOGEN

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Verticillium wilt of potato is a vascular disease caused by Verticillium dahliae. Due to its soil borne nature and its difficulty to eradicate by rotation, or chemical means, the use of tolerant or resistant cultivars is the ideal way to control the disease.

During the last five years we have carried our extensive field trials by planting candidate cultivars and breeding lines in heavily infested soils, under conditions of high evaporation, an environment, which leads to excellent symptom development. We differentiate between tolerant, resistant, and susceptible lines by estimating the visual symptoms, isolating the pathogen, and measuring the yield. On the basis of this work, several new cultivars have been introduced into our agricultural system to replace some of the previously grown cultivars which were very susceptible to Verticillium wilt.

All the cultivars tested were bred and selected for characteristics other than Verticillium tolerance, such as yield, tuber quality, etc. Although the work mentioned above has been successful in determining tolerance in a number of cultivars it is expensive, time consuming and dependent on vagaries of climatic conditions. This system cannot be used as a method for screening breeding material on a large scale basis.

In a program conducted to elucidate some of the factors involved in symptom expression we determined that an extracellular toxic entity produced by V. dahliae is involved in pathogenicity. Our results confirm observation of others that at least two phytotoxic, heat stable, high molecular weight protein lipopoly succharide (PLP) complexes can cause damage to potato leaf tissue of susceptible lines but not of tolerant ones. One of the two toxic fractions does not exist in extracellular products of a non pathogenic, spontaneous mutant of V. dahliae.

The bioassay is performed by injecting the toxic entity into the parenchyma tissues of detached leaflets and observing chlorosis and necrosis in the susceptible material. Since potato leaf tissue may per se be damaged by injection of high molecular weight compounds we use as a negative control the similar, but non toxic fraction produced by a non pathogenic mutant of V. dahliae.

The possibility was considered to use this method for large scale screening of cultivars, seedlings and breeding lines for a tolerant characteristic against Verticillium wilt. Such testing could be done under highly standardized conditions which could be repeated several times a year if necessary, due to the fact that the test can be carried out on very young greenhouse grown plants.

A cooperative program to examine this possibility was instituted with the Foundation for Agricultural Plant Breeding at Wageningen, with the active participation of Ir. H.T. Wiersema and with support from the Dutch government.

As of now we have had about 80% success in finding positive correlations between our laboratory and field tests, mainly in dihaploid lines.

Parallel to our work with detached leaflets we attempted to study the effect of the toxic fraction on protoplasts and callus tissue derived from leaf tissue of susceptible and tolerant cultivars. Our results indicate differential reaction of the toxin upon isolated protoplasts under specific conditions, whereas no differential activity was seen on callus tissue derived from the same cultivars.

POTATO IN SUBTROPICS FOR THE YEAR 2000

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In India, nearly 90 per cent of the acreage under potato is in sub-tropical plains and tropical humid plateau region of the Southern peninsula, and potato is grown during the short photoperiod of winter months. The North Indian hill, temperate region, accounts for only 10 per cent area under the crop, in the sub-tropical and tropical belts.

Production problems and priorities are different from those in Europe and America. The long-day adapted varieties of Europe and America do not suit Indian conditions (Pushkarnath, 1964). At the Central Potato Research Institute organized in 1949, a genetic pool was created with collections from outside and within the country to serve as the base for breeding efforts. Indigenous established cultivars of unknown origin were more like Andigena than Tuberosum, presumably because of the ecological selections in the evolutionary process (Pal and Pushkarnath, 1951).

They had the inherent advantages of good adaptability, slow degeneration, and good storage characteristics.

The initial efforts for potato improvement in India were to increase gross production because of food requisites. Therefore, yield and other commercial attributes were decisive for selection of new hybrids. Quality improvement and breeding for disease resistance received 'second-place' attention but disease-free seed, balanced fertilizer application, crop protection measures and optimum productivity-cultural technology were given due attention.

Total production increased from 1,543,000 metric tonnes in 1949-50 to 10,125,000 metric tonnes in 1978-79 with yield increasing from 7.5 tonnes to 12.8 tonnes (Table 1).

In view of the nation-wide occurrence of viruses and late blight, the necessity to incorporate resistance or to control these diseases in every commercial variety was realized. Production of disease-free stocks was streamlined. Problems of regional importance such as brown rot in Kumaon hills of U.P. and plateau regions, wart in the West Bengal hills, cyst nematodes in the Nilgiris, charcoal rot in the Northern Plains and frost in Punjab, Haryana and foot-hill (Tarai) areas also attracted attention.

Table 1. Area, production and average yield per hectare of the potato in India - 1949-80 to and estimated figures per 1984-2000.

Year	Area (000'ha)	Production (000'm tonnes)	Yield (t/ha)
1949-50	234	1543	6.59
1954-55	266	1764	6.63
1959-60	362	2733	7.55
1964-65	429	3605	8.40
1969-70	496	3913	7.89
1974-75	587	6225	10.60
1975-76	622	7306	11.74
1976-77	620	7171	11.57
1977-78	664	8153	12.27
1978-79	790	10125	12.81
1979-80	693.1	8306.1	11.98
1984-85 1/	850	120.000	14.12
1989-90 1/	900	150.000	16.66
1994-95 1/	950	185.000	19.48
1999-2000 1/	1,000	220.000	22.00

Source: Estimates of area and production of principal crop in India - 1977-78. Directorate of Economics and Statistics, Ministry of Agriculture and Irrigation, Govt. of India, Sixth Seventh Issue, January, 1979.

Socio-fiscal influence on crop raising

Potato is a highly input and labour intensive crop and the capital investment need often exceeds monetary capacity of the farmers. The gap between calculated maximum production and the actual yields is wide such as highest yield of nearly 70 tonnes per hectare in the national competition plots and average productivity of about 13 tonnes per hectare. The present-day varieties require heavy nutrition, and good cultural conditions. In some areas in developing countries the yields may be as low as 6 tonnes/ha due to financial inability to invest for high production. For such growers, who form a major farming community, varieties that can produce reasonably well on poor fertility, reduced cultural care, low moisture regimes and minimum plant protection obligations need to be developed to ensure a good profit in return for basal input investment. Some of the old indigenous Indian varieties like Phulwa, Satha, O.N. 1645 exhibited such features and they are still being cultivated by the marginal peasantry in spite of introduction of high yielding varieties. New hybrids capable of responding with high yields to moderate tending are required to fill the varietal gap.

Re-defining of quality values

Potato production shows a surplus in the last five years. However, much production

is lost due to insufficient per capita consumption, transport facilities, inadequate storage, and processing.

High dry matter, starch and protein contents would improve quality of chips, cubes and wafers. Potato is recognized as a good source of energy for adults and infants providing energy and high-ratio assimilable protein (Table 2) and some essential vitamins and minerals. At the Central Potato Research Institute, utilizing the efficient donor sources of tuberosum and andigena germ-pool, hybrids combining high dry matter content with yield factors have been developed.

Table 2. Energy and protein production of tropical food crops and potatoes in countries between 20° N Lat and 30°S Lat.

Crop	Available Energy[1/] (10^3 kilos joule)	Protein[2/] (kg)
Potatoes	166	1.1
Sweet Potatoes	167	0.5
Cassava	154	0.2
Maize	133	0.8
Yams	121	0.6
Rice	120	0.6
Chick Peas	67	0.9
Dry Beans	40	0.6

Source: D.E. Van der Zaag. "Potato Production and Utilization in the World". "Potato Research" 19 (1976) Table 7.

1/ Production kg (kilo joules /ha/day

2/ Production kg /ha /day

Usually, there is a natural inclination to improve the dietary quality of crops by breeding for higher protein content. Potato protein, in this respect is important due to its assimilability efficiency. Methionine content of potato is inversely associated with its dry matter percentage (Fitzpatrick et al., 1964). Emphasis should be laid on breeding for high dry matter and breaking the correlation for enhancing the protein constituent.

Farmers' resources are limited and attention should be paid to produce varieties tolerant to high temperatures in improvised country stores, with prolonged dormancy, but with quick response to dormancy breaking chemicals.

Quality of a crop is described in terms of its nutritive value. However, storage behaviour, transportability and suitability for specific usage are equally important.

Breeding for resistance to diseases and pests

The emphasis on breeding for resistance factors has been on immunity or near immunity. The most widely used source for resistance to late blight has been Solanum demissum which possesses both kinds of resistance, field immunity, race specific (Black, 1957; Mastenbroek, 1966; Toxopeous, 1956) and field resistant, race nonspecific).

A similar situation exist in S. stoloniferum (Black 1950; Malcomson and Black, 1966). It is difficult to separate out the two resistance systems in the derived progeny.

In Canada and West Germany, attempts were made by Graham (1963) and Ross (1966) to breed varieties with 'exclusive field resistance' from S. demissum and S. stoloniferum respectively. At the Central Potato Research Institute, a programme of exclusive field resistance utilizing a diploid species S. verrucosum has been in progress. Triple hybrids have been synthesized involving S. verrucosum x S. phureja x S. tuberosum (dihaploids) which exhibit a good level of field resistance. Hybrids are being evolved by back-crossing with S. tuberosum to improve their commercial value. Some of the hybrids in (BC_3 stage) approximate the commercial standards and carry a practical level of field resistance (Sharma et al., 1978).

A total of 75 races of Phytophthora infestans, 2 biotypes of Synchytrium endobioticum and 2 races of Pseudomonas solanacearum have been recorded. In addition distinct strains have been identified in case of Rhizoctonia solani (8 strains) Alternaria solani (2 strains) and Phoma species. The situation with probability of appearance of more new races, emphasises the desirability of breeding for 'Horizontal resistance' as a future strategy. In view of a variety of diseases and pests simultaneously active against the crop during its growth phase, it would be necessary to breed "columns of Integrated Resistance" encompassing the major pathogenic and insect-pest situations. The fact that the expression of infectivity is a result of multifacet interaction between the micro-flora and fauna, external conditions of environment, soil strata and host plant further underlines the imperativeness of the approach for integrated control in the coming years.

Breeding for stress situation

India represents seven varied ecological situations. The sensitivity of potato to different photo-periods, temperature, and humidity does not allow a single or a group of varieties becoming equally successful in all locations. Intensive cultivation in certain areas and marginal cropping in others causes disbalanced distribution and great price disparity. Varieties should be developed with 1) high efficiency for utilizing limited available water 2) low respiratory and transpiration rates having a compact plant canopy, and 3) deep root system technology of water conservation.

Under equinox conditions of plateau areas and other warmer regions, tolerant varieties are required. The breeding efforts of the Central Potato Research Institute have produced hybrids of Tuberosum-Andigena origin (hybrid HC 294) with capacity to withstand temperatures up to 30°C without appreciable depressive effect on yield (Khanna, 1966). Solanum chacoense is also being evaluated for producing hybrids tolerating high temperatures (Sharma, 1977).

Frost is a problem in the western plains of Punjab, Haryana and Tarai areas in Uttar Pradesh. Already varieties like Kufri Sheetman and Kufri Dewa having a fair level of frost tolerance have been released. Solanum curtilobum, S. acaule and S. spegezzinii are other sources for tolerance to frost and selected clones are being used as parents. An efficient and critical method for frost resistance is needed. The studies at CPRI have shown that for quick estimation, thickness of pallisade tissue and numbers of pallisade layer indicate the extent of tolerance in a line; more layers imparting higher degree of tolerance (Tiwari and Sukumaran, 1978).

Post-harvest technology and energy resource exploration

India produces around 10 million tonnes of potato per year with approximately 11 kg/capita consumption leaving a substantial amount for other uses at home or exported raw for seed or table use. Alternative uses as cattle feed or starch must be explored. CPRI has designed a solar dehydrator for quick drying of chips, wafers, cubes, shreds and nodules, etc., without involving energy consumption in the present scarcity situation (Singh and Singh, 1979). Days are not far off when more and more dehydrated products will be available commercially.

Post-harvest technology involves preservation of the crop without deterioration in quality or quantity. The varieties differ in tuber density, storage efficiency, dormancy and capacity to withstand handling in transport. CPRI has fabricated several non-refrigerated experimental cool stores (Sukumaran et at., 1980) in which stocks can be stored in good condition for 4 to 5 months in summer.

New technological approaches for adoption and investigative pursuits are:

Dihaploid synthesis and feasibility of commercial exploitation

Establishment of "Parental Lines" was initiated by Reiman et al., in 1956. Hougas and Peloquin (1958) identified lines of Solanum phureja efficient in inducing dihaploids in cultivated species S. tuberosum. These were used for stabilizing desirable attributes at 2n chromosome level for breeding at dihaploid level. CPRI is running a programme to this end, as also to study the genetics of complex characters, developing monoploids and trisomics for detailed cytological studies on chromosomal behaviour and utilizing them for hybridization.

True seed commercial crop

Growing a morphologically 'homogenous' crop of potato from true seed is now considered possible. Ramanujan (1954) began inbreeding commercial varieties to stabilize major characters by repeated selfing. Krantz (1946) considered the inbreeding technique of great promise in stabilizing characters without loss of vigour and fertility. The International Potato Center, Lima (Peru) started an ambitious programme on the basis of reported results of its practicability from China and New Zealand etc. Peloquin (1979) proposed a workable scheme for developing appropriate lines with high combining ability for homogeneity. CPRI is also continuing a programme in this respect.

In countries such as India where multiple and relay-cropping are practiced, early maturity of varieties is a necessity. A true seed crop, takes about 6 to 7 months in comparison with 3 months required by a seed tuber crop, reduction of time for a TPS crop may be possible in the year 2000 with continued research. Phenotypic similarity in plant type, tuber characters and maturity may be realized, but incorporation of resistance to diseases, pests,

and physiological conditions will require more time for incorporation in true seed hybrid populations.

After TPS cultivation becomes common, pest and pathogen spectra are bound to change. More emphasis is, therefore, to be given for incorporating resistances against TPS transmitted organisms.

Gene engineering

The first attempt at raising a plant from protoplast was successfully made by Tabeke et al., (1971) in tobacco. Melchers (1976) regenerated a potato plant from a single mesophyll protoplast cell. The advancement has opened up great possibility of cell-level genetic engineering through somatic hybridization by physical transplantation of nucleus from one cell into the cytoplasm of the other. The barriers of incompatibility, self-and-cross sterility, genomic compartmentalization and pre-and post-fertilization blockages encountered in the traditional breeding method can thus be overcome. Induction and isolation of desirable mutations at single cell level achieved in Nicotiana by Carlson (1970) is yet another field of promise.

Cropping systems

Programmes of intensive land use per unit time have to be launched, specially in developing countries. Multiple and relay cropping, mixed and companion crop growing and 'tier' cultivation are to be introduced. Varieties which may thrive well and yield normally under partial shade have to be evolved. Resistance to diseases in the variable plant microclimate of the new cropping systems would be preferable.

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POTATO PRODUCTION IN KENYA: POTENTIAL AND LIMITATIONS

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Abstract

Importance of the potato both as food and cash crop, is pointed out. Main growing areas and methods of cultivation are outlined. Some of the factors are discussed which account for the big differential between national average yields and potential yield, (notably lack of enough certified seed, diseases, particularly late blight (Phytophthora infestans) and viruses, poor storage and lack of efficient marketing systems. This paper also highlights some of the solutions being attempted by the Ministry of Agriculture in cooperation with the private sector and parastatal farming concerns.

Importance of the potato in Kenya

The potato, which was introduced in Kenya about eighty years ago, has over time become a very important food and cash crop which has expanded in cultivated areas, in total production, and in usage as an important item of diet for a large cross-section of the Kenya population. It is grown in the highlands, mainly in the Central Province on the Eastern ridges of the Aberdare mountains: Kiambu, Murang'a and Nyeri Districts; Eastern Province in the northern slopes of Mt. Kenya; and notably in Meru District, Rift Valley Province in Nakuru District (Molo, Mau Narok, Ol Kalau). Considerable potential exists for production in Western Province, notably Kakamega District.

Popularity of the potato as a food is due to its palatability, ease of cooking, and convenience. Between one-third and one-half of Kenyas population is estimated to consume potatoes. Annual total hectarage (two crops per year) is estimated at 75,000-100,000 grown by 450,000 farmers, with probable production between 400,000 and 500,000 tonnes annually. Approximately two-thirds of production is consumed on the farm, and only about 100,000 tonnes enter the regional or interregional market. In a few special areas, notably Meru, a greater proportion is marketed in the urban centres such as Nairobi. As many as 150,000 people (about 3 per cent of the labour force active in agriculture) are employed in the potato industry.

Potato production techniques and systems

Ecological requirements

The potato, a cool temperate crop, is grown at 1500 to 3000 m above sea level in Kenya. For most of East Africa 25 mm of rain per week during the growing season is adequate. Virtually all the crop is rainfed, hence the seasonality in production. Out of season irrigated crops are only a small fraction of the total national crop. No potatoes are grown at the coast due to high temperatures and heavy rainfall of 750 mm.

Production technology and potential

The crop is grown by small holders owning 0.2 to 2.0 ha in widely spread areas. Since mid-1960s the number of large scale growers has declined considerably.

Land is prepared mainly using hand tools such as hoes and fork jembes. Some farmers may hire a tractor and a plough. Due to the smallness of the plots, mechanization is not easy. In most areas farmers are recommended to plant early, at the beginning of the rain season although some are late in preparing their land. Areas with better rainfall distribution, e.g. Kissi and Kericho can plant in each month. Most farmers use their own seed usually of small size tubers planted at 2.0 - 2.5

tonnes per hectare. If there is a crop failure a seed shortage crisis results. Very few farmers plant certified seed because of high cost and some certified varieties may not be popular, and certified seed is often unavailable in adequate amounts.

Kenya potato industry is based on about ten varieties, namely, Anett Kenya Baraka, Kerr's Pink, Roslin Eburu (B53), Roslin Gucha, Roslin Tana, Roslin Ruaka, R. Karura, Roslin Athi, many of which were introduced from Scotland (U.K.), The Netherlands, and West Germany. The potato industry is based on ten or so varieties. Varietial purity is not much insisted upon and often several varieties are grown mixed on one farm.

Importance of or need to use fertilizers is recognized by most farmers. Manures and fertilizers although recognized as needed by most farmers are used only by a few. Durr (1977) reported that only about 25% of the farmers surveyed used compound fertilizers of which only 1% met the recommended standards. Fertilizer rates applied were sub-standard due to lack of cash. The main nutrients applied are nitrogen or phosphorus in diammonium phosphate at rates from 100 - 500 kg/ha.

Weed control is a prerequisite to high yields in Kenya being a labor intensive exercise and expensive requiring up to 2-3 weedings by hand using hoes and fork jembes. There are prospects for chemical weed control using sencor.

A good number of growers, particularly in Central Province practice crop rotation. A four-year cycle is recommended. Approximately 15-25% of potato stands are intercropped often with maize and beans. Maize lowers yield due to shading to which the potato is very sensitive.

The most devastating disease is late blight (Phytophthora infestans) controlled usually by spraying Dithane M-45, 3-4 sprays per season.
Otherwise, the whole crop may be lost. Rates and frequency of fungicide application are below recommended levels due to lack of capital and losses are considerable. Although most recommended varieties possess some resistance, none are completely resistant, Kerr's Pink, the most popular is extremely susceptible yet farmers persist in growing it.

Bacterial wilt (Pseudomonas solanacearum) can be severe at altitudes below 2000 meters. It is controlled by planting certified seed and by crop rotation. Virus diseases, particularly virus leafroll which causes considerable yield losses are best controlled by planting clean seed preferably certified seed. Rarely do farmers plant certified seed.

The potato tuber moth (Phthorimaea operculella), by far the most serious in field and stores, is best controlled by insecticidal sprays and earthing up of the plants in the field and dusting the tubers with insecticidal dusts during storage. Aphids which spread virus diseases, particularly at the lower altitudes should be controlled by spraying the seed crops in the field. Control of aphids during storage of the seed is advisable since some spread of the viruses occurs in seed stores.

Most varieties are mature and ready for harvesting within 3 to 3.5 months. Harvesting takes place 4 months after planting and is done manually using sticks, for hoes, and pangas. The tubers are then roughly graded ready for the market or storage.

Yield varies considerably between areas. Average yields are very low compared with potential yields due to poor production techniques and poor quality seed. National average yield is estimated at 5-7 tonnes/ha.

In Meru where standards of management of potatoes is above average, yields are twice as high as the national average. With good husbandry in the high potential areas, yields of 30-40 tonnes/ha are obtainable (Table 1).

Table 1. Potato yields at Kibirichia (Meru) and Nyeri[1/]

Variety	Yield[2/]	
	Kibirichia	Nyeri
Anett	45.0	39.8
B53	41.4	23.4
Atzimba	37.8	20.9
Kenya Baraka	34.7	26.2
Kenya Arika	26.7	26.2
Pimpernel	13.0	34.8

1/ Source: Holler, H.J. 1972/73
2/ tonnes/ha

Factors limiting production

Lack of good quality seed

Farmers use their own seed or may buy from neighbors. Although Kenya's potato seed certification programme has been in operation for several years, there is no adequate supply of certified seed at planting time. Reasons for this shortage are:

Ware and seed grade prices are not rationalized and move freely depending on market forces. Ware potatoes have almost always been higher priced than seed and seed is consequently sold as ware.

Certified seed production zones (above 2400 m) are far from potato growing areas. For example, Molo, a good potato seed area is 500 km away from important potato growing areas in Central province.

Some of the certified varieties are not popular because of late maturity or poor consumer preference. Thus, many farmers continue to depend on Kerr's Pink, for which there is no certified seed supply because it is highly preferred by the consumers.

Lack of reliable certified seed storage between harvesting and planting causes many small seed growers to sell soon after harvest rather than risk storing without any certainty of future price.

As a solution, plans are under way to have a large proportion of certified seed crop grown on large-scale parastatal farms and for distribution to be by large seed companies. Thus, the seed may be less expensive to the farmers since it is cheaper to certify large-scale production than small widely scattered plots.

Storage and marketing

Seasonality in production results in glut in the market during harvest and scarcity during the offseason. It is aggravated by weather factors and disease outbreaks especially late blight. Consequently, prices fluctuate considerably, making potato growing and marketing a highly risky business. In most of the production areas suitable storage does not exist and post-harvest losses are high. To avoid further crop loss the farmers off-load their crop on the market immediately after harvest. Thus, they are not able to take advantage of high prices later.

Individual traders operating almost as a monopoly in potato buying and selling, buy the surpluses directly from the farms or local trading centers offering very low prices. Consequently the farmer's profit margin is not enough for him to buy fertilizers and fungicides to increase production. The high marketing risks also discourage the trader to invest in storage which would certainly improve marketing efficiency.

Slight modification in traditional storages coupled with use of sprout suppressants (for ware potatoes) would make it possible to store potatoes for 3 to 4 months with minimum loss in quality. However, even if storage problems were solved transportation and availability of market information must also be improved. Organizing widely scattered growers owning 0.2 to 2.0 ha for marketing purposes is difficult. The farmers also grow other crops complicating matters further.

Pest and diseases

There is urgent need to intensify the already ongoing research work on breeding more late blight-resistant varieties.

Potato viruses X, S, Y, A and leafroll, found throughout the potato growing areas in Kenya, are transmitted and spread by aphids. Myzus persicae is the most efficient vector in Kenya, Macrosiphum euphorbiae transmits PVY and PVA while Aulacorthum solani is the vector of PLRV. Leafroll can cause yield reductions to 70% depending on the potato variety (Table 2), with Kenya Baraka-highly susceptible and Anett, less so. Leafroll is more common in the lower, warmer areas, than at altitudes of over 2400 m. It is generally accepted that seed production is best confined to areas above 2400 m. Leafroll is high in degenerated seed stocks. Effects of other viruses are less clearly defined. To ensure production of virus free seed, virus research work in the national research programme should be strengthened to study degeneration of improved stocks in different potato producing areas as well as the relationship between virus infection and other factors contributing to low yields.

Bacterial wilt probably introduced in the country around 1940, was previously thought in the mid-1960s to be a serious obstacle to the potato industry. It is no longer a major threat provided that seed-producing farms are restricted to altitudes above 2400 m. At these altitudes, bacterial wilt is almost non-existent, apparently because of the comparatively lower soil temperatures which are sub-optimal for survival and the spread of the organism. Even at the lower altitudes where still most of the crop is grown, a

Table 2. Mean yields of six different seed stocks of Kerr's Pink and the percentage infection with virus leaf-roll, PVX and PVS.

Seed stock	Infection with Leaf-roll %	PVX %	PVS %	Mean yield 1/ 2/
Elite seed (PRS) control	0.5	1	6	53.250
Meru 1	15	100	63	33.750 (63.4)
Meru 2	15	100	71	31.375 (58.9)
Meru 3	48	100	90	30.000 (56.3)
Meru 4	36	100	76	28.875 (54.2)
Meru 5	27	100	81	25.250 (47.4)

Standard error of the mean = 3.546

Source: Potato research in Kenya 1970-1976: Technical report on the Potato Research Scheme for the Ministry of Overseas Development, London.

1/ Kg/plot;

2/ % of control in parenthesis.

4-year rotation cycle coupled with planting of clean seed will contain the disease to sub-economic levels. Maize in the rotation was better than beans, in controlling wilt but grass was even better. Research work in Kenya showed that seed-borne inoculum is more important than the soil-borne inoculum in ensuring survival and recurrence of bacterial wilt.

Although breeding for bacterial wilt resistance is no longer a priority in the national programme, more research work on factors controlling survival of the bacterium is required in order to place control measures on a stronger footing.

In conclusion, provided the four problems of seed supply, disease, storage and marketing can be solved, the potato has a very strong future in Kenya.

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SYSTEMATIC EXPLOITATION AND UTILIZATION OF WILD POTATO GERM PLASM

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Summary

Authors propose systematic ways of utilizing hitherto unused sources of wild and cultivated potato germ plasm to produce breeding populations with a wide spectrum of resistances.

The importance of concurrent research into taxonomic and evolutionary relationships of various species to each other, as well as the utilization of these species is highlighted.

Breeding and selection within wild species before they are crossed to cultivated breeding lines is emphasized in order to minimize the negative effects of a wild x cultivated cross. The long term nature of this work and the comparative advantage CIP has in carrying it out are stressed.

Introduction

The ide of using wild potato species to improve the gene pool of cultivated potatoes is not new. Hybrids of Solanum demissum and the cultivated potato were reported as early as 1849 (Klotzsch, 1849), before the advent of modern genetics and taxonomy. Some of the early hybridizations were almost certainly attempted with triploid forms of S. commersonii and S. maglia (Hawkes, 1958). These failed because the concept of triploid sterility had not yet been understood.

These attempts were the first stage in the utilization of wild potato species (Hawkes, 1958). The second stage began when Salaman (1910) demonstrated that the Mexican species S. demissum and its hybrids with S. tuberosum were resistant to Phytophthora infestans. However, most of the early research was handicapped by a lack of taxonomic knowledge in spite of Dunal's work in 1852. The German taxonomist G. Bitter (1912 - 1914) reviewed the whole genus and created a sound taxonomic basis for further work at about the time of Salaman's first publications.

From 1925 to 1933 the Russian geneticists and plant breeders Vavilov, Bukasov and Juzepczuk collected genetic material in the New World and revealed an amazing variability in both the cultivated and the wild potato gene pool. They discovered the polyploid series of cultivated potatoes, described a large number of new wild species and demonstrated unknown resistances against frost and fungal diseases in this material.

The Russian expeditions were followed by others, and living potato collections were established in the Soviet Union, the United States, Germany, and England.

Plant breeders soon started to use wild and primitive cultivated materials because of valuable specific resistances that had been identified in this germ plasm.

The 1976 issue of the "Index of European Potato Varieties (Stegemann and Loeschke, 1976) lists 595 potato cultivars. Of these, 381 are pure S. tuberosum and 191 have S. demissum, 11 S. vernei, 6 S. acaule, 3 S. stoloniferum, 2 S. spegazzinii and 1 S. salamanii in their pedigree.

This rather small group of wild species has contributed only minimally to the widening of the genetic basis of modern cultivated potatoes due to the need of many generations of backcrosses to the cultivated parent. Most of this material had been introduced into Europe through some of the collecting expeditions of the 1920's and 30's. The period that began with these expeditions and which continues to the present has been called the third phase of the utilization of wild potatoes (Hawkes, 1958).

Apart from using these wild species in modern potato breeding, increasing use has also been made of primitive Andean cultivated potatoes which has resulted in varieties and breeding lines with specific resistances. Pertaining to breeding for resistance to Phytophthora infestans, Simmonds wrote in 1976: "The tetraploid cultivars seem to have the genetic capacity needed and wild species are probably not necessary."

Since then more has been learned about the use of wild species, and potato breeding may well be entering a fourth phase in the use of wild germ plasm.

The present state at CIP

With the establishment of the International Potato Center (CIP) in 1972, collecting wild germ plasm was greatly intensified, and a great part of the natural distribution range of the tuber-bearing Solanums has been covered by about 25 collecting expeditions. More expeditions are planned for the future in order to obtain a broader genetic base for those species of which only a few living collections are known or which are only known as herbarium specimens. The wild germ plasm collected by CIP was systematically screened for a variety of resistances during the past years. This testing concentrated mainly on four areas:

1. Resistance to bacterial wilt
2. Resistance to the potato cyst nematode
3. Resistance to the root-knot nematode
4. Resistance to virus diseases

This search resulted in two diploid breeding populations with single or combined resistances. The first is a population with resistance to bacterial wilt and root-knot nematode (MBN population) (the spanish acronym of "Marchitez Bacteriana Nematodos") consisting of three wild and one primitive cultivated species (Mendoza and Jatala, 1978; Jatala and Mendoza, 1978):

S. sparsipilum
S. chacoense
S. microdontum
S. phureja (cultivated)

The second population has resistance to one or more pathotypes of the potato cyst nematode (PCN population). Accessions of the following species are resistant against one or two pathotypes of Globodera spp., not all of these were, however, included in the breeding population:

S. bulbocastanum	S. gourlayi
S. megistacrolobum	S. lignicaule
S. capsicibaccatum	S. papita
S. stenophyllidum	S. sparsipilum
S. cardiophyllum	S. oplocense

Systematic breeding efforts were started with the MBN population. Through the functioning of 2n gametes in tetraploid x diploid (TD) crosses the resistance traits of the diploid population were transferred to 4x andigena and tuberosum germ plasm.

This type of 4x/2x hybrid combines two genomes from a wild species and two from a tetraploid cultivated potato. Such combinations result normally in a setback in agronomic characters, yield, and tuber quality. However, work with triploid natural and re-synthetized S. juzepczukii has demonstrated that even combinations of one cultivated and two wild genomes may result in high yielding clones with excellent agronomic characteristics (Schmiediche et al., 1980). This was also shown in 4x/2x crosses, as well as in backcrosses to the tetraploid parent of some 4x/2x hybrids. The best families in the first group of TD crosses yielded an average of 1.34 kg/plant and one single clone had 1.45 kg. A backcross of these TD clones to 4x clones adapted to the lowland tropics produced average family yields of 1.59 kg/plant; the best clone yielded 3.0 kg. These results were obtained with less than 20,000 seedlings.

The MBN population contained also resistance to the potato tuber moth (PTM) and charcoal rot which is important in India. Both resistances were incidental and had not been sought originally. Resistance to PTM was especially marked in clones that had a particular accession of S. sparsipilum in their pedigree.

The PCN population contained species from the Mexican as well as the South American gene pool, two pools can only be hybridized with great difficulty, and often bridge species must be used (Hermsen and Ramanna, 1973). Accessions of S. capsicibaccatum and S. lignicaule exhibited a remarkable degree of resistance to two pathotypes (P_4A and P_5A of G. pallida, and the two species were successfully hybridized. For S. capsicibaccatum it was the first time that it was crossed with a species from outside its series. These hybrids will now be crossed with cultivated diploid or haploid material.

Even wild species only distantly related to the tuber-bearing Solanums might be used to obtain specific resistances. The potato leafroll virus (PLRV) resistant South American, non-tuber bearing species, S. etuberosum is possibly more distantly related to the potato than is the genus Lycopersicon to which the tomato belongs (Ramanna and Hermsen, 1979).

However, it has been possible to cross S. etuberosum with the Mexican tuber-bearing species S. pinnatisectum (Hermsen and Taylor, 1979). After doubling the chromosome number, the completely sterile S. etuberosum x S. pinnatisectum (EP) hybrid became a fertile amphidiploid (Hermsen et al., 1981) which was further crossed with tuber-bearing species. In some portions of the EP hybrids the PLRV resistance of the S. etuberosum parent was retained. The eventual transfer of this resistance to the cultivated gene pool is no doubt a long process, but the results obtained so far illustrate that it is possible to obtain resistances from even distantly related species. Most tuber-bearing wild potatoes are, however, sufficiently close to the cultivated germ plasm that as a rule straight hybridization is possible.

High resistance against PLRV and the potato spindle tuber viroid (PSTV) has been found in S. acaule and hypersensitive resistance to PVY and immunity to all previously known strains of PVX as well as a high degree of resistance to PVX_{HB} have been detected in S. sparsipilum. Both species can easily be crossed with cultivated potatoes.

The use of wild species in breeding

Traditionally, desired resistances found in wild species were transferred to cultivated germ plasm through direct crosses with a series of backcrosses eliminating undesirable wild characters in the following generations.

A second approach under current use at CIP is the population breeding approach (Mendoza and Rowe, 1977). It consists of the following steps: A base population with the desired resistances is assembled, intercrossed and the F_1 raised. The F_1 seedlings are screened against the pathotypes in question, the susceptible individuals eliminated and the survivors intercrossed for a next cycle of selection. With this type of recurrent selection it has been possible to increase the frequency of the desired genes rapidly and thus the needed resistances.

Simultaneously, selection for improved agronomic characters - still within the wild population - is carried out. The efficiency of this is increased if some diploid cultivated or selected dihaploids of cultivated tetraploid potatoes are integrated in the same population. When this material is finally crossed to cultivated material, the setbacks with regard to agronomic characters and yield are considerably reduced as has been shown in preliminary results obtained from TD crosses.

Research for a Ph.D. thesis at the University of Birmingham is at present carried out at CIP, and the research student is attempting to transfer to cultivated potatoes the resistance against the potato tuber moth, the potato cyst nematode and potato leafroll virus, all found in different groups of wild species.

Future strategy for the use of wild species

Some of the results described above and others to be published indicate how the vast pool of wild germ plasm could be used in the future.

Although actual collecting of most wild potato germ plasm may now be considered almost complete, classification of the collection still continues. Taxonomic classification can by no means restrict itself to morphological descriptions and the classification of a given specimen into one of the existing taxa or the possible creation of a new taxon. Modern experimental taxonomy includes studies on the evolution, crossability, cytogenetics and resistances of a given accession.

So far, approximately 180 wild species have been recognized and about 10% of this gene pool has been utilized in breeding. New wild species have continued to be described, some as late as 1981.

The task of classifying, evaluating, and utilizing this germ plasm must be calculated in terms of decades rather than only a few years. Which is the best strategy for CIP to employ in order to use some of the better-known germ plasm quickly and effectively?

Further breeding efforts should probably concentrate on the series most closely related to the cultivated potato, and the most obvious series is Tuberosa, because most of its members cross fairly easily with cultivated potatoes. The series Acaulia, Megistacroloba, Commersonia and Conicibaccata from the South American gene pool and series Demissa and Polyadenia from the Mexican gene pool have all been crossed with cultivated potatoes and their use should be explored further. Both, evolutionary and taxonomic research as well as screening for resistances and utilization in breeding can go on concurrently.

In some cases it is essential to know the exact phylogeny of a taxon to resynthetize it, if necessary. This is particularly important if a certain species, such as S. juzepczukii for instance, exists only as a triploid which is sterile or if the genetic base of a taxon is to be widened for better adaptation or disease resistance. This was shown to be advantageous with the cultivated diploid species S. ajanhuiri, which is difficult to breed per se because of its reduced male fertility and its narrow genetic base (Huamán, 1980).

Conclusion

CIP is ideally situated in the center of variability of a large number of useful wild potato species and appears to be the best and logical place for simultaneous work on biosystematic studies in wild species as well as their use in breeding.

New methods to overcome crossability barriers are attempted with the help of modern tissue culture methods, some pioneered at CIP. As these projects develop, they may result in parental lines with desired characteristics and resistances needed by breeders in other parts in the world.

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FLUID DRILLING OF SOMATIC POTATO EMBRYOS AS A MEANS OF CROP ESTABLISHMENT

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One of the greatest limiting factors for potato production in the warmer regions of world is the lack of virus-free seed stock for planting of the crop. Current production of certified virus-free seed is limited to either the cooler temperate regions or to tropical mountainous areas, causing transportation costs to be a major hindrance to expanded consumer crop production. Reducing these costs has received a high priority for research programs in both developing and developed countries. Such projects included evaluation of growing potato from true seed (Accatino, 1979), stem and leaf cuttings (Lauer, 1977; Stallknecht, 1972), certified tubers that can be grown and multiplied in local plantings for one to two successive plantings (CIP, 1979) and tissue culture (Goodwin et al., 1980 a and b; Marani and Pisi, 1977; Pennazio and Vecchiati, 1976).

In the United States, most of these methods are not of practical use in their present state of the art. Variability and questionable product acceptability is a major problem with true seed, since marketing is often based on clonally propagated cultivars. Stem cuttings and subsequent tuber formation would be labor intensive and unacceptable. In the United States seed tuber production is restricted to the northern regions. Due to climate restrictions and virus vectors it is not possible to multiply certified seed in warmer regions. This results in a doubling of the farmer's seed cost in southern U.S.A. because of the transportation costs.

Potato tissue culture propagation was evaluated by several people (Lam, 1977b; Roest and Bokelmann, 1976; Roca et al., 1978). Probably, one of the more significant results of tissue culture studies was the identification of variability among plants that were derived from individual cells of a single plant (Gunn and Shepard, 1981; Shepard and Totten, 1977; Shepard et al., 1980). Some variability observed in tissue cultured plants may be a result of environmental factors and may not be genetic in nature (Denton et al., 1977). Other forms of variability may be short lived genetic variants resulting from the presence of mutable loci (McClintock, 1950a, 1950b, 1951).

Other benefits that were realized from potato tissue culture include disease indexing and maintenance of disease-free clones (Gregorini and Lorenzi, 1974; Lizarraga et al., 1980; Mellor and Stace-Smith, 1977; Pennazio and Redolfi, 1974; Quak, 1977; Quazi and Martin, 1978; Schmidt and Grahsl, 1977; Shepard, 1978; Skirvin et al., 1975; Wang, 1976; Wang and Huang, 1975) and general storage of large germplasm collections (Westcott et al., 1977). Probably one of the more important developments yet to come from potato is reliable somatic embryo production.

Somatic embryogenesis was documented in several crops including: sweetpotato (Hwang et al., 1980; Tsay and Tseng, 1979), wheat (Schaeffer et al., 1979), papaya (Litz and Conover, 1981, 1982) and hybrid potato callus (Jackobsen and Sopory, 1978; Jarret et al., 1980; Kohlenbach and Geier, 1972; Ramanna and Hermsen, 1974; Sopory and Tan, 1979; Sopory et al., 1978; Sopory, 1977; Sopory and Rogan, 1976; Weatherhead and Henshaw, 1979). This technique may be the most efficient method for large scale production of clonal planting material. Potato anther successes indicate that other tissues, with the appropriate media, may lend themselves to the desired embryo production. Litz and Conover (1981, 1982) observed that papaya ovule integument was a good source tissue for polyembryony. Somatic embryo production in this instance would have been adequate for scaling up to a commercial type operation. It also was documented that explant origin and the physiological state of the parent tissue affect callus formation and organogenesis (Quraishi et al., 1979). The addition of activated charcoal to the culture media was associated with improved somatic embryo formation (Litz and Conover, 1980; Sopory et al., 1978). Specific amino acid addition, reflecting the amino acids from the parent tissue, was also suggested as being helpful for the induction of somatic embryos (Weatherhead and Henshaw, 1979). Thus, several variables remain to be tested, which may provide the appropriate combination for reliable somatic embryo production.

Although generally not desirable in clonally propagated material, limited amounts of genetic variability, in some instances, would be desirable. The screening of potato callus cultures for resistance to late blight (Behnke, 1980), early blight (Matern et al., 1978) and amino acid analogs (Carlson and Widholm, 1978; Widholm, 1976) was accomplished, although plants regenerated from resultant callus do not always possess the same character. Screening for tolerance to other diseases or environmental stress, eg., high salt or aluminum concentrations and other maladies may well be possible. Somatic embryo screening should be possible. Large populations of immature somatic embryos could be subjected to various selection pressures. Since embryos are already differentiated, it would be possible to overcome the difficulty of regenerating plants from callus cells.

Once a reliable and efficient system for somatic embryo production is realized, conditions for precocious germination of natural embryos must be established. The transfer of sterile embryos to a non-sterile medium requires special consideration. Current procedures for establishment in the soil of tissue culture-derived plantlets are labor intensive and too costly for large scale production.

A major difference between pregerminated seed and mature somatic embryos is the lack of an endosperm associated with somatic embryos. Thus there must be a transitional period between somatic embryo production and transfer of the plants to soil that would enable the embryos to overcome their deficiencies. This might involve retention of somatic embryos in culture to permit limited germination, followed by a period of exposure to light for optimal chloroplast development. This could be accomplished in a mulit-stage continuous flow culture system, where the appropriate growth regulators and external factors could be applied at the appropriate stage. Production of planting material by means of somatic embryogenesis could also be a means of maintaining disease-free clonal planting material. Virus indexing would be necessary only at the initiation of the culture procedure.

Efforts in the handling and drilling of pregerminated vegetable seed may provide the appropriate means for embryo establishment. These efforts include plug-mix planting (Bryan et al., 1973) and fluid drilling (Currah et al., 1974). Plug-mix provides a means of planting imbibed seeds with a pre-moistened stabilizing agent such as an artificial soil mix. Fluid drilling allows for the planting of seeds that have germinated to the point of radical emergence. In this case germinated seeds are suspended in a water-based gel prior to planting. Potential large scale use of fluid drilling resulted in various degrees of mechanization ranging from a push planter

concept (Lickorish and Darby, 1976) to tractor drawn seeders (Bryan et al., 1978; Currah et al., 1974). Recent advances in mechanization have lead to the development of inexpensive planting devices that combine the merits of fluid drilling and plug-mix planting (Shaw et al., 1980).

Due to uniformity requirements, vegetables were a good crop group for fluid drilling experimentation (Bryan et al., 1978). These developments have direct application to vegetable production in the tropics (Bryan et al., 1980). Fluid drilling of somatic potato embryos directly into the field would be the most efficient method of utilizing tissue cultured plants for crop establishment. The fluid drilling system is flexible enough to allow for modifications that can include the addition of growth regulators and plant protectants to either the gel or the soil mix.

Experiences with plantlets derived from true seed, indicate that special fertilization and soil conditioning may be necessary for optimal growth. Plant genotype effects might also be a major factor. The ability to efficiently produce somatic embryos and plantlet vigor must be taken into consideration in selecting clones for somatic embryogenesis.

It may be necessary to develop systems for the fluid drilling of somatic embryos in a sterile or pasteurized seedbed where more special attention could be provided. Plants could be transplanted to the field following a method similar to the planting of soil blocks. Alternatively, the plants could be left in the seedbed until tuber development was accomplished. In this case tubers would be taken to the field for crop establishment.

Applications for developing countries could include the establishment of somatic embryo production packages, where all media is pre-measured and starter somatic embryo cultures could be supplied. Cultures could be multiplied on a local basis. A facility where equipment and media could be sterilized and a trained technician to maintain the cultures would be necessary; however such a facility would be considerably less in cost than certified tuber importation.

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MEASUREMENT AND RESPONSE OF POTATO CULTIVARS AND SPECIES TO HEAT AND DROUGHT STRESS

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Introduction

The adaptation of plants to many environmental stresses are due to natural or artificial selection pressures acting on variable populations to cause a change in gene frequency for more adaptive plant properties and processes. In recent years interest has focused not only on the response of plants to water and high temperature stress, but also on the importance of morphological and physiological mechanisms of adaptation to water and high temperature stress. Field observation and experimental studies have shown that potato varieties differ greatly in physiological and morphological response to heat and drought stress.

A greater knowledge of the specific effects of high temperatures and/or limited soil moisture supply on potato varieties or clones and the establishment of reliable methods of selecting heat and drought resistant clones would increase the effectiveness of potato breeding programs. Ultimately the climatic range of commercial potato production would be extended. Consequently, the objectives of these studies were:

To determine potato varietal characteristics in water usage.

To determine the immediate and protracted effects of high temperatures on potato plants.

To ascertain the morphological and physiological factors associated with potato plants in response to heat and drought.

To compare and evaluate various methods for measuring heat and drought resistance in Solanum species and families.

To evaluate these species and families for heat and drought resistance.

Water usage

Under field conditions with a high level of soil moisture, high yielding potato varieties extracted large amounts of soil moisture from the top 5 feet of soil in comparison with low yielding varieties. Production efficiencies (bu./acre/in. of water) of varieties did not differ significantly but were greater for high than low yielding varieties (Table 1). Water loss from plants severed from root systems was less per unit of leaf area for varieties with large leaf areas than those with small leaf area (Table 2). Water loss from excised leaves was from 1.5 to 1.8 times the corresponding water losses from intact plants severed from their root system (Table 2).

Heat machine (high temperature chamber) and electrical conductivity tests

These two methods were used to measure heat resistance of potatoes. With the heat machine method potted plants (7 weeks post-emergence) were placed in a heat chamber and maintained at a constant temperature (55.5°C for 1959 data, and 50°C for 1980 data) for a standard length of time (4 hours) and at known relative humidity (60%). The degree of wilting (slight to total) based on a scale of 1 to 10 for 1959 data and 1 to 9 for 1979-80 data was estimated. They were then transferred to the greenhouse for a period of 3 weeks following which the percent of permanent damage or resistance classes were estimated. The other method which is based on electrolyte leakage from leaf discs bathed in deionized water and measured by an electrical conductivity bridge was used to estimate the percent heat injury after exposure to 50°C for 1 hour.

Table 1. Yield, water used and production efficiency of potato varieties.

Variety	Yield (bu./a.)	Water (in./ft.^{2})	Production efficiency (bu./in. used)
Katahdin	188	8.40	22.7
White Cloud	166	7.50	22.0
Triumph	158	7.80	20.6
Progress	155	7.55	20.5
Red Warba	149	7.81	19.1
Irish Cobbler	145	7.40	19.5
Pawnee	135	6.27	21.6

Table 2. Coefficient of leaf area, water loss and volume of water lost for potato varieties.

Variety	Coef. Leaf Area[1/]	Water loss (32 hrs) Leaf %	Plant[2/] %	Water Volume Leaf Unit[3/]
Kennebec	400	43.7	31.9	0.11
Katahdin	264	46.1	26.3	0.16
Dazoc	264	49.5	30.4	0.19
Triumph	240	47.2	19.4	0.18
Red Pontiac	160	51.9	32.4	0.24
Irish Cobbler	120	46.2	35.6	0.32

1/ Number of leaves x number of leaflets x size of leaflets (rating 1 to 5; 1 approx. 2 sq. in ; 5 = approx. 10 sq. in.)

2/ Intact above ground portion of plant severed from root system.

3 Grams or cu.cm./unit of coefficient of leaf area.

Wilting degree was directly correlated with percent permanent damage or resistance classes and percent heat injury (Table 3).

Heat injury and temperature treatment

The heat susceptible variety, Triumph, averaged 67.5% heat injury over the range of temperatures (45°C to 60°C), while Irish Cobbler, a heat tolerant variety, averaged 57.5%. Heat injury as measured by the electrical conductivity method increased as temperature increased. The relationship between treatment temperatures and heat injury was sigmoidal for both varieties. (Figure 1).

In heat chamber tests using a series of temperatures ranging from 110° to 135°F a test temperature of 120°F (48.8°C) was

Table 3. Degree of plant wilting, plant damage and heat injury.

Variety	Wilting degree 1/ 1959	Wilting degree 1/ 1979-80	% Permanent damage 2/ 1959	Resistance classes 3/ 1979-80	% Heat injury 4/ 1979-80
Dazoc	6	5.3	25	2.8	42.8
Irish Cobbler	7	2.9	50	1.8	29.1
Katahdin	5.7	3.5	60	2	33.9
Kennebec	6.5	3.5	70	1.8	22.4
Red Pontiac	4.7	5.8	52	3.2	42.1
Triumph	10	6.0	90	3.3	54.8

1/ Estimates the degree of wilting at the end of each heat machine test run with a scale of 1 to 10 (1959, data) and a scale of 1 to 9 (1980, data).

2/ Indicates percent of tissue destroyed.

3/ Indicates the degree of permanent damage to plants after exposure in the heat machine; classes 1 and 2 (resistant) = 0 to 50% leaf damage; classes 3 and 4 = 5 to 100% leaf damage plus stem damage.

4/ Indicates percent heat injury determined by the electrical conductivity method after exposure to 50°C for 1 hour.

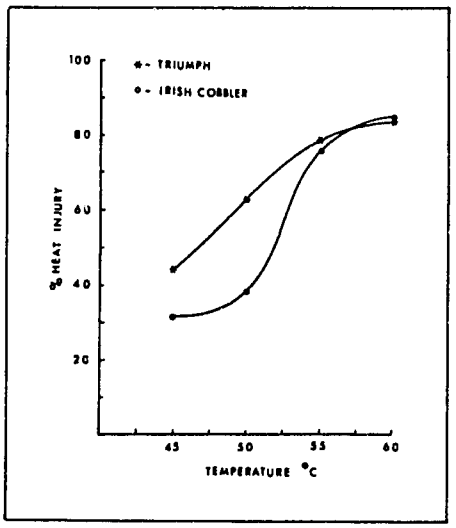

Figure 1. Heat injury of two potato varieties at different temperatures.

the critical temperature for potatoes. At this temperature the widest range of plant damage occurred among varieties. As indicated 50°C produced comparable results with the electrical conductivity method.

Heat injury and physiological age

Percent heat injury of old leaves (lowermost leaves) and young leaves (upper-most) were determined (Table 4). The heat injury averaged from 18.7% in the lower leaves of the plant (physiologically old) to 26.5% in the upper-most leaves (physiologically young). The greatest difference between old and young leaves was observed for the highly susceptible variety Triumph. The youngest leaf tissues from upper-most leaves sustained considerably more injury upon temperature treatment than did older leaf tissues from lowermost leaves. In other genotypes (e.g. Atlantic, only minor differences were observed among samples collected from upper and lower leaves. Thus sampling procedures for genotypic comparisons should consider physiological age of leaves.

Generally positive relationships exist between heat resistance classes ranging from susceptible to resistant and characteristics such as leaf area, tuber yield and regrowth index. Indications are that

Table 4. Heat injury for old leaves and young leaves of five potato genotypes, 1979.

Genotypes	% Heat injury: Old leaves	% Heat injury: Young leaves
Irish Cobbler	21.6 b 1/	17.1 a 1/
Atlantic	20.2 b	21.8 b
54.58-H33	17.8 ab	22.6 b
Norchip	15.4 a	27.4 c
Triumph	18.6 ab	43.4 d
Mean	18.7	26.5

1/ Mean values with the same letter are not significantly different at the 5% P. level based on Duncan's multiple range test.

as resistance of plants to heat injury increases leaf area of plants increases. Strong negative correlations were found between heat resistance, plant height and wilting degree. Resistance to heat injury decreased as plant height and wilting degree increased.

Significant differences in heat resistance and other characters observed or measured were found not only between potato species, but also among potato genotypes within the species (Tables 5, 6). The wide range of variability is useful to potato breeders to select desirable genotypes in a breeding program to develop hybrids with desirable yield characteristics in heat and drought stressed environments. Because potato varieties are reproduced vegetatively total genetic effects can be reproduced vegetatively.

Estimates of heritability (broad sense) based on individual plant basis and family mean basis indicated that resistance to heat injury, plant height, leaf index, and wilting degree, are highly heritable characters in potatoes. Consequently selection for heat resistance should be effective. The greatest genetic gains in resistance to heat injury in potatoes may be accomplished by selecting the most resistant families (family mean basis) or by selecting the most resistant genotypes (upper most 10%) on an individual plant basis.

Table 5. Heat injury of potato cultivars.

Genotypes	% Heat injury 1/
Triumph	43.38 bc 2/
Dazoc	42.82 bc
Red Pontiac	39.66 bcdef
Norgold	37.68 bcdefg
Haig	33.34 cdefgh
Katahdin	33.87 cdefgh
Norchip	27.42 ghijkl
Denali	23.83 hijkl
Superior	23.41 hijkl
Kennebec	22.42 hijkl
Atlantic	21.81 ijkl
Shurchip	21.17 jkl
Irish Cobbler	17.07 l

1/ Indicates percent heat injury determined by the electrical conductivity method after exposure to 50°C for 1 hour.

2/ Indicates means with the same letter are not significantly different at the 5% P. level based on Duncan's multiple range test.

Table 6. Family means for heat injury in Solanum species grown from true seed.

Species and genotype	Collection number	% Heat injury 1/
S. sucrense	HHC 4596	72.17 ab 2/
S. stenophyllidium	PI255530	67.68 abc
S. chacoense	OKA 6117	60.60 bcde
S. venturii	OKA 5645	57.25 cdef
S. sucrense	HHC 4594	56.63 cdef
S. commersonii	OKA 6180	52.34 defg
S. commersonii	OKA 5138	50.32 defgh
S. venturii	OKA 4908	49.99 defgh
S. spegazzinii	OKA 5690	48.50 defgh
S. oplocense	OKA 5478	46.89 efgh
S. stenophyllidium	PI255529	46.34 efgh
S. commersonii	OKA 5071	40.49 gh
S. oplocense	OKA 5477	40.22 gh
S. chacoense	OKA 6116	37.66 h
Mean		54.29

1/ Indicates percent heat injury determined by the electrical conductivity method after exposure to 50°C for 1 hour.

2/ Indicates means with the same letter are not significantly different at the 5% P. level based on Duncan's multiple range test.

IMPROVEMENT OF THE POTATO AS AN ENERGY RESOURCE

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Introduction

In the Nebraska potato improvement program, one of the main objectives is to evaluate potatoes as an energy resource ethanol in addition to a food resource. The potato, a starchy raw product, requires some extra preparation for ethanol production when compared with grain. In

World War II, one of the major sources of fuel or energy was alcohol made from potatoes. Very high starch or carbohydrate varieties were developed and grown specifically for that purpose. About 70% of the total potato production in Germany during World War II was for alcohol as a fuel source.

In the later years of World War II it was determined that three times more butyl alcohol than ethanol could be obtained from 100 pounds of potatoes. Production of butyl alcohol as an energy source from all agricultural products should be considered. The supply of alcohol became short in the United States in World War II. In Idaho a program was developed for use of cull potatoes for manufacture of alcohol. Under the War Food Administration Program in 1944 inactive sugarbeet factories or plants were used to dehydrate potatoes. In other words potatoes were shipped to and put through the equipment in inactive sugarbeet factories for dehydration. The dehydrated product was then shipped to alcohol plants to produce alcohol from the dehydrated product. This was an inefficient system.

The dehydrated product was equal to corn in ethanol yield. The government developed a program for producing industrial and beverage alcohol after World War II from surplus potatoes. During that period 13.3% of the alcohol made was made from potatoes and 16.5% from grain so the amount of alcohol being produced from grains and potatoes was about the same. Seventy percent was produced from molasses from sugarbeet or sugarcane factories or from petroleum products. In 1947 much of that production went into the production of commercial butyl alcohol. Eighteen percent of the 35 million bushels of surplus potatoes in 1947 were converted to butyl alcohol rather than ethanol; 34% of 133 million bushels in 1948 were converted to butyl alcohol. In the last 35 years economics and government policies have limited the use of potatoes for the production of alcohol.

With that brief history of alcohol production from potatoes consider the potato itself as the raw product for ethanol production. From 100 lbs. of tubers are obtained 11 to 19 lbs. of starch and 1 to 3 lbs. of sugar and 7 to 10 lbs. or 1.2 to 1.6 gallons of ethanol. A yield of 1000 cwt./A. produces 1200 to 1600 galons of ethanol per acre. As specific gravity increases carbohydrate content increases from 13.7 to 19.7%. In term of gallons of alcohol per ton of raw product the carbohydrate converts to from 21 to 30 gallons per ton. The standard conversion factor for sugarbeets is 22 gallons per ton and 105 gallons for grain. The varieties of potatoes that are produced in Nebraska presently range from 1.070 to 1.090 specific gravity. With todays varieties 23 to 28 gallons of alcohol per ton should be obtained. As yield per acre and gallons/ton increases the cost per gallon on the basis of the cost of the raw product ranges 0.62 to $1.85.

The Nebraska Program

The Nebraska project, as revised two years ago has three basic objectives: (1) to identify varieties for maximum carbohydrate and alcohol production on an acre basis; (2) to identify and develop specific cultural and storage practices to minimize production costs and energy requirements; (3) to establish good cost-returns and energy-return data for alcohol production from potatoes.

For the best 13 of 52 different varieties and selections tested, (Table 1) yields ranged from 313 cwt. up to 700 cwt. per acre in 1980. The gallons per cwt. of potatoes as actually determined by fermentation and distillation ranged from 1.13 gals/cwt. up to 1.39 gals/cwt. which converts on an acre basis to 386 to 811 gallons of alcohol which equals approximately 82% of theoretical production. In addition, stillage (the residue after distillation) ranged from 4900 to 9300 lbs. per acre. It's value per 100 lbs. in terms of animal feed is 28 cents. Crystal and Bounty in the trials had identical carbohydrate content per 100 lbs., but 3% more alcohol was produced from a 100 lbs. of Bounty than from Crystal. The efficiency of recovery of alcohol can be highly dependent on the variety.

Table 1. Ethanol and stillage from potatoes, Nebraska. 1980.

Variety	Yield cwt./A.	Ethanol gal./cwt.	Ethanol gal./A.	Stillage lbs./A.
*Neb.40S. 72-2	624	1.30	811	9391
*Neb.40. 57-3	700	1.15	805	9100
Red Pontiac	564	1.14	646	6796
Onaway	560	1.13	638	6944
Kennebec	544	1.20	655	7426
*Progress	520	1.23	640	7228
*Platte	520	1.18	614	7072
*Bounty	491	1.22	597	6874
Katahdin	486	1.21	588	6634
Triumph	486	1.15	559	6294
Larouge	454	1.16	527	5970
Denali	378	1.31	495	5746
Crystal	355	1.19	422	4863
Sebago	342	1.13	386	4463
Lemhi	313	1.39	434	4914

* Nebraska developed varieties.
** varies depending upon carbohydrate content and efficiency of conversion by fermentation.

Cultural and storage practices and modification of them need to be considered if potatoes are grown for alcohol production. Some ethanol plants are built to use cull potatoes rather than specifically producing an efficient variety to make alcohol. With this concept, cull potatoes can be used to utilize every pound of potato that is produced per acre. If potatoes are grown for the potato chipper or processor about 75 to 85% of the yield per acre is marketed; the rest are cull potatoes. About 60 to 75% of what is produced per acre can be marketed on the fresh market; the rest are culls. However production of alcohol at the lowest cost per gallon requires growing maximum tonnage of carbohydrate at the lowest cost and energy use per acre regardless of the size, shape, or condition of the potato. For example, Fusarium rot is a tremendous problem for the seed market, the fresh market, or the processor. It's no problem in alcohol production. Internal net necrosis is a market defect caused by the virus leafroll that is transmitted by the aphid. One of the high costs in potato production is to control the aphid. Probably 95% of what is spent on insect control in potatoes is because of the effect of insects on the market quality. If potatoes are specifically produced for alcohol production the costs for insect and disease control can be reduced. However, some insects such as the psyllid and diseases such as spindle tuber reduce yields and must be controlled. Efficient use of fertilizer must also be considered. In 1970, fertilizer was costing $38.00 and in 1980 was $89.00 an acre. Storage, must also be evaluated. Storage for fresh market or processing potatoes is costing $1.75 to $2.25/cwt. of capacity to construct. To make alcohol out of potatoes, tubers can be handled like sugarbeets. The BTU energy transfer in a pile of potatoes is about the same as in a pile of sugarbeets. The Nebraska program intends to put potatoes in sugarbeet piles and monitor temperature and heat exchange and make alcohol out of those potatoes when they are removed from the sugarbeet pile. Also four years of data developed at the Mitchell Station and at the Alliance Station, indicate that we can again go back to pit storage or trench type storage of potatoes for alcohol production.

The National Program

The Nebraska program is also contributing to a national program evaluating potatoes as an energy source; also involved are: Washington (Dr. Mark Martin); Idaho (Dr. Joe Pavek); Maine (Dr. Raymon Webb); and North Dakota (Dr. Bob Johansen). Washington (Table 2) had two types of trials called "maximum culture" and "standard culture". In the "maximum culture" trial they maximized every input which maximized total cost but produced 669 to 1406 cwt. per acre. In "standard culture" trials, yields with the same varieties ranged from 468 to 701 cwt. per acre. In Idaho trials with basically the same varieties, yields were 358 to 507 cwt/A.; in Maine, 265 to 501 cwt/A.; in Nebraska 106 to 700 cwt. per acre. In Washington with maximum culture, theoretical ethanol production from tubers was 730 to 1535 gals. per acre (also 22 to 244 gals. of alcohol per acre were produced from the vines) and with standard culture ethanol yield was 512 to 767 gals. per acre: In Idaho, 448 to 729 gals. per acre were produced from tubers; Maine, 311 to 672 gals. from tubers and 32 to 133 gals. per acre of alcohol from vines. In Nebraska actual ethanol yield as determined by fermentation and distillation was 119 to 811 gals. per acre. Using the theoretical conversion factor of 1.3 gal/cwt. the estimated yield was

Table 2. Value and costs of ethanol from potatoes (1980).

	Per acre		Cost/acre
Washington			
Culture			
Maximum	$1241 to	$2616	$1339
Standard	$ 940	$1399	$ 937
Idaho	$ 762	$1239	$ 800
Maine	$ 528	$1142	$ 600
Nebr.	$ 252	$1379	$ 610
	Net value per acre		
Washington			
Maximum	$ 98 to	$1277	
Standard	3	462	
Idaho	- 38	439	
Maine	- 72	542	
Nebr.	-358	769	

148 to 980 gals. per acre. The value of ethanol ranged from $252 to $2616 per acre. Net value of ethanol per acre ranged from minus $358 to plus $1277 per acre.

BIO-ENERGY AND FOOD POTENTIAL OF THE POTATO AND ITS LIMITATIONS IN THE YEAR 2000

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Brazil is poorly endowed with organic fuels, either coal or petroleum; consequently, it imports more than 80 percent of its petroleum needs. The rapid growth of its automobile and truck fleets as well as the rapid economic growth of the country and the rise in world petroleum prices have caused petroleum to become a major component of its total import bill, increasing from 10% in 1972 to more than 50% of its export earnings in 1980. This has also resulted in growing foreign debt that in 1981 added up to 60% of foreign exchange earnings in terms of repayment and service charges.

Brazilian agriculture has been called upon to make a major contribution through the expansion of crops with energy-producing biomass capacity to reduce Brazil's heavy dependence on imported petroleum.

At the present time in Brazil, there are many processes and concepts which are being developed and studied for producing alcohol fuel from several types of biomass feedstocks. Massive investments aimed at reducing dependence on imported oil have been made, notably through the conversion of sugarcane to alcohol.

Approximately one quarter of the food produced in Brazil and throughout the world never reaches the consumer because the food is damaged before consumption. Typical examples include cull potatoes, that increase the percentage of seed potato used in developing countries and constitute the major portion of potato used as feed in developed countries.

Brazil does not at present consider the potato among the major feedstocks being evaluated for alcohol production. Still, as a part of agricultural waste utilization, cull potatoes which constituted about twenty percent of total production in 1980, 400,000 tons, represent a potential source of alcohol production.

The use of white or Irish potatoes to make fermentation alcohol is well established even though their high food value usually makes them at best marginally profitable. Still, where culls are available in quantity, they are usually low enough in cost to make alcohol production profitable. There is also a byproduct from fermentation of potatoes having significant feed value. The quantity is much less than distillers' grains and the protein content is lower, so the value as an animal feed supplement is not as great as for distillers' grains when using corn or other grains. Still, it could substitute up to 60 percent of the original potato feed value.

The potato is a major food crop both in terms of calories and protein. The nutritional or biological value of protein in potato is rather high. As a world average, 230 kg/hectare of potato protein is greater than in wheat, rice or grains. However according to CIP Potato Atlas, in 1972-74 some 39% of world potato production was used for feed or was wasted.

According to a recently published report, a medium potato (about 5 ounces) has about 110 calories, 4-5 percent of the daily caloric total needed by the average adult. At the same time, the potato supplies nearly 5 percent of the protein, 5 percent of the iron, 8 percent of the phosphorous, 10 percent of the thiamin, 11 percent of the niacin, and 50 percent of the vitamin C, as well as large percentages of vitamin B-6, copper, magnesium, iodine, and niacin needed daily by the average adult. (Brody, 1981).

Up until now, the main criteria of agricultural productivity were calculated in terms of yields per hectare, yield per man, return per unit of capital invested or even yield per cubic meter of water used in irrigation (Israel) depending on the scarce production factor; land, labor, capital, or water.

Under the stimulus of the new price of energy, the next few years are likely to see the emergence of more rational ways of using fuel in farming.

As a result, it is suggested that the returns also be considered in terms of energy output in relation to input used to produce a given crop.

An evaluation of all the energy requirements for sugarcane, cassava, cotton, corn, soybeans, wheat, eucalyptus, pinus, tomato and potato crops was performed in the state of Sao Paulo. Process analysis, input-output matrix technique and/or a combination of both were used in energy computations by Moreira et al. (1980). All data were collected on active farms of the state; these computations can be used as an upper limit for Brazil, since Sao Paulo is the most developed state of the country.

Energy input for potato production (Moreira et al. 1980) was 17,263 Mcal/ha in Sao Paulo. Table 1 shows that in terms of liquid fuel production (in this case alcohol) potato uses more energy input in the agricultural phase than energy output in potential alcohol without even considering energy requirements in the processing that includes the distillery stage. last is also higher than in other crops according to "Gasohol" (Development, Planning, and Research Associates, 1978).

Table 2 indicates that in terms of food output per energy input, potato is also the most energy intensive crop with the possible exception of tomato.

Table 3 considers total potential food production per year per hectare, including two crops when the growth cycle is less than 6 months. This approach shows that if land is the limiting factor, potato production may be the best alternative when locally produced food is needed and fuel is abundant.

The energy crisis is an opportunity for farmers and agricultural research workers to turn their creativity to shaping energy alternatives suitable to farm needs. It is suggested that lower energy input and higher output characteristics be considered in breeding and selection of the new varieties. Research orientation formulated during the next few years will affect what people throughout the world will eat and use as energy in the year 2,000.

Table 1. Energy output input ratios for selected crops in terms of liquid energy.

Crops	Input (Mcal/t) 1/	Fuel Potential 2/	Potential Output 3/	Output-Input Ratio 4/
Sugarcane	50.95	56.25	360.00	7.07
Cassava	122.76	162.00	1,036.00	8.07
Tomato	366.99	-	-	-
Corn	696.74	315.00	2,016.00	2.89
Wheat	1,148.61	318.75	2,040.00	1.77
Potato	704.61	86.25	552.00	0.78

1/ Energy in Mcal/t. See Moreira et al. 1980. Table III-3.
2/ Potential in liters alcohol/t. See Jacobs and Newton, 1938. p. 26.
3/ Output in alcohol as Mcal/t. (liters alcohol times 6.4)
4/ Third column divided by first column.

Table 2. Food (Mcal/t and kg of protein) output in relation to input in the agricultural phase of selected crops.

Crops	Potential Food Supply 1/		Food Output/ Energy Input 2/	
	Mcal/t	Protein (kg/t)	Mcal/ Mcal	Gr. of Protein/Mcal
Sugarcane	370	-	7.26	-
Cassava	1,490	8	12.14	65.17
Tomato	210	8	0.57	21.80
Corn	3,610	120	5.18	172.23
Wheat	3,320	127	2.89	110.60
Potato	750	18	1.06	25.55

1/ Calory and Protein Content estimated on data of the "Estudo Nacional da Despesa Familiar", ENDEF, Rio de Janeiro, Fundacao Instituto Brasileiro de Geografia e Estatistica (Household Budget Survey 1975), 1979, various volumes.
2/ Moreira et al. table III-3.

Table 3. Potential food production per ha per year using two crops or fraction of yield depending on growth cycle.

Crops	Yearly production (t/ha/Year) 1/	Food Energy (Mcal/ ha/year 2/	Protein (kg/ha/ 2/
Sugarcane	63.20	23,384	-
Cassava	13.50	20,115	108.00
Tomato	-	-	-
Corn	5.60	20,216	672.00
Potato	49.00	36,750	882.00
Wheat	2.40	7,968	304.80

1/ Based on the growth cycle of: sugarcane, 15 month; cassava, 18 months; tomato, 5 months; corn, 4 months; potato, 4 months and wheat, 5 months.
2/ Same as tables 1 and 2.

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APPROPRIATE PLOT SIZES AND SPACINGS FOR FIELD EXPERIMENTS WITH POTATO LATE BLIGHT

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Results from small field plot experiments with Phytophthora infestans and other aerially disseminated plant pathogens are often confounded by both inoculum loss from individual plots and inoculum exchange between neighboring plots (James et al. 1973; 1976). This problem, "interplot interference", causes differences between treatments to be smaller in experimental plots than they would be in large fields (Van der Plank, 1963). One practically important consequence is that the effectiveness of disease control measures (e.g., fungicide applications or resistant cultivars) can be severely underestimated. To help deal with this problem, we constructed a simple model that can be used during experiment planning to select plot sizes and spacings that limit interplot interference to negligible levels.

Materials and methods

Our model is based on the equation proposed by Kiyosawa and Shiyomi (1972) to describe disease gradients resulting from point sources of inoculum.

$$y = a \cdot e^{-bx} \qquad \text{(Equation 1)}$$

where x = distance from the inoculum source
y = infections per unit area of foliage
a = a constant describing infections per unit area of foliage at the source
and b = a constant describing steepness of the disease gradient. Small values of this parameter indicate flat gradients. Large values indicate steep gradients.

By modifying this equation to include two dimensions and multiple sources of inoculum, we were able to estimate the proportion of inoculum lost from and exchanged between small experimental plots. The impact of this inoculum loss and exchange on epidemic progression was then predicted by using a second model that described disease development. We examined the predictions of two different models - one a discrete version of the common logistic equation (Pielou, 1977), and the other a complex simulation of potato late blight that appears to accurately characterize epidemics in our experimental system (Bruhn and Fry, 1981).

Equation 1 contains an unknown parameter, 'b', which must be estimated (the other parameter in Eqn. 1, 'a', is not practically important for reasons discussed elsewhere (Paysour and Fry, 1983). We determined the value of b for our experiments with potato late blight by quantifying the distribution of lesions around a point inoculum source of P. infestans in both irrigated and non-irrigated potato plots.

The models can be used to predict a relationship between plot size and epidemic severity. Model validation was initiated by comparing this prediction with actual potato late blight development in irrigated field plots of various sizes. Experiments were conducted in 1980 with four plot sizes and the cultivars Hudson and Sebago, and in 1981 with five plot sizes and the cultivar Katahdin.

Results and discussion

In non-irrigated potato plots, we estimated b to equal 0.82 m^{-1} in one case and 1.29 m^{-1} in another (Figure 1A and 1B). The value of b was somewhat larger when irrigation was used, with b = 2.10 m^{-1} in one plot (Figure 1C). These estimates of b allowed us to predict a specific relationship between plot size and severity of potato late blight epidemics. Figure 2 shows our predictions for irrigated potato plots. Epidemic severity should increase asymptotically with increasing plot size and approach a maximum when plots are about 25-50 m^2. Actual potato late blight development in irrigated field plots of various sizes agreed qualitatively with this prediction (Figure 3A and 3B). In both the 1980 and 1981 experiments, epidemic severity increased with increasing plot size until plots were about 13-30 m^2. Absolute differences between treatments were not as large as expected; however, we believe the predicted and observed outcomes were similar enough to indicate the models are substantially realistic.

The two models of disease development were used to simulate field experiments in order to determine the proportion of inoculum loss and exchange that can be tolerated without significantly altering relative differences between treatments. Experiments with treatments that differed widely in disease severity were more affected by a given proportion of inoculum loss or exchange than were experiments involving treatments with similar disease severities. As a result, the maximum "tolerable" proportion of inoculum loss or exchange decreases with increasing difference in disease severity between treatments.

Plot size and plot spacing can be manipulated by the researcher to limit inoculum loss and exchange to a "tolerable" amount. Our models can be used to identify the specific sizes and spacings required. Generally, to reduce interplot interference to negligible levels, experiments involving pathogens that produce flat disease gradients require larger plots and wider spacings than do experiments with pathogens that produce relatively steep gradients. This point is illustrated by Table 1, which gives required plot spacings for a range of experimental conditions. For experiments with potato late blight in non-irrigated plots of 25 m^2, plot spacings of about 2.4-6.0 m are needed, depending on the expected maximum difference in disease severity between treatments. For similar experiments in irrigated plots, where disease gradients are steeper, plot spacings should be about 0.6-2.6 m. Notice that plot spacing can be reduced somewhat by increasing plot size, although the trade-off required may not be justified.

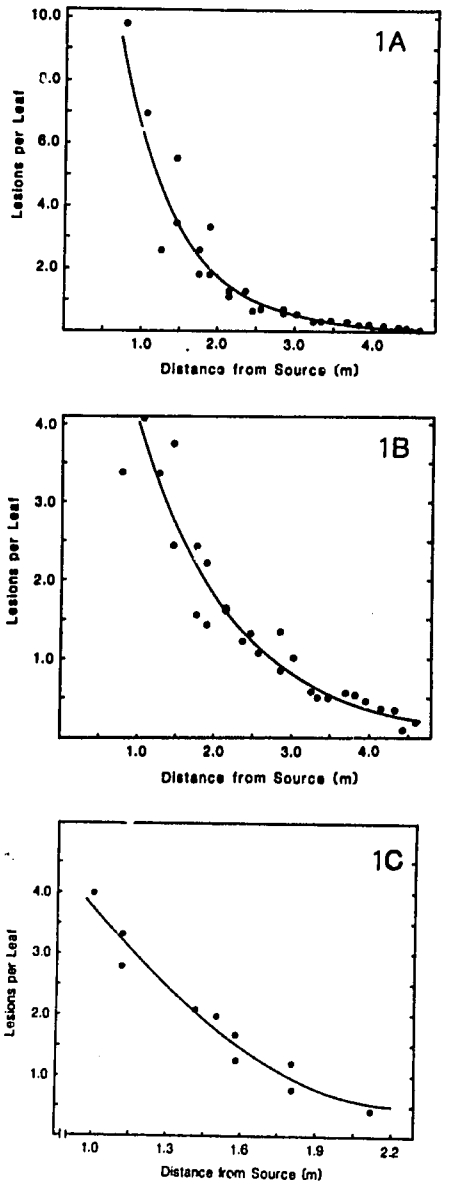

Figure 1. Disease gradients produced by P. infestans in potato plots. A and B were measured in non-irrigated potatoes, with each point representing the average of 50-100 leaves. C was measured in irrigated potatoes, with each point representing the average of 100-200 leaves. The parameter 'b' was estimated to equal 1.29 m^{-1}, 0.82 m^{-1}, and 2.10 m^{-1} for A, B, and C, respectively.

We believe our models can be useful in designing a wide range of field experiments. It seems probable that many researchers will not feel our suggested plot sizes and spacings are practically feasible, particularly when dealing with pathogens that produce flat disease gradients.

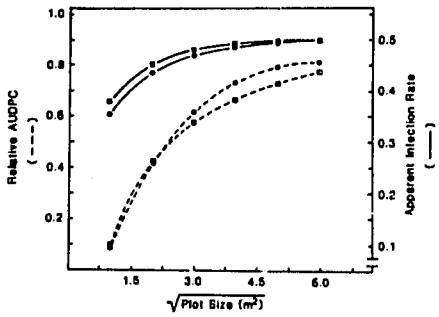

Figure 2. Predicted effect of plot size on potato late blight epidemic severity in irrigated plots, using two different models of disease development - Bruhn's simulation model (O), and a discrete logistic model (o). AUDPC = area under the disease progress curve.

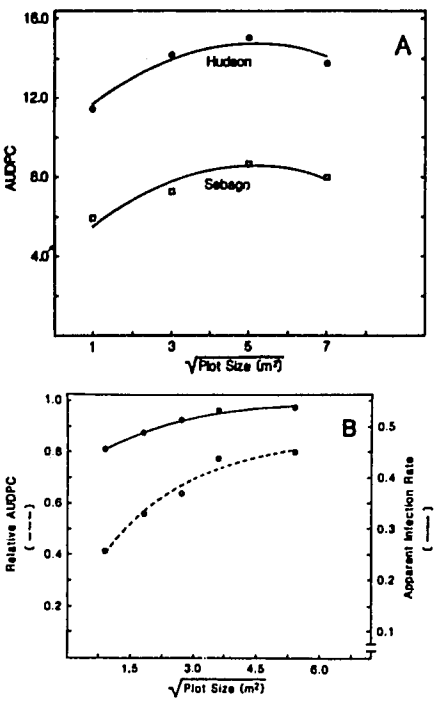

Figure 3. Observed relationship between plot size and potato late blight epidemic severity in 1980 (A) and 1981 (B) field experiments.

Table 1. Plot spacing[1/] required to limit positive interplot interference to a negligible level in experiments with potato late blight.

Maximum difference in disease severity	Plot size (m^2)	Required plot spacing(m) non-irrigated potatoes ($b \approx 1.0\ m^{-1}$)	irrigated potatoes ($b \approx 2.0\ m^{-1}$)
	9	3.0	1.1
2-fold	25	2.4	0.6
	100	1.4	0.2
	9	5.3	2.3
10-fold	25	4.7	1.9
	100	4.0	1.3
	9	6.6	2.9
50-fold	25	6.0	2.6
	100	5.5	2.0

[1/] Plots are assumed to be square in shape.

However, we cannot hope to obtain experimental results that accurately reflect processes in commercial agriculture unless interplot interference is limited to low levels.

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POTATO CROP IN PORTUGAL PROSPECTIVE SITUATION AND UTILIZATION; AND THE CHALLENGE OF AGRICULTURAL SYSTEMS OF NORTHERN COASTAL AREAS

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Utilization

Potatoes were introduced by Spanish soldiers at the end of the eighteenth century. Potatoes are now the most important single annual crop in Portugal with about 6% of gross agricultural product.

Portuguese human consumption of potatoes is very high by Western European standards. Per capita consumption varies with internal production averaging around 95 kg. This compares with an average of 77 kg in the European Economic Community and 37 kg in Italy. Only Ireland and Spain have similar levels of consumption (Table 1) (Comission des Communautés Européennes, 1980: Concalves Ferreira, 1978; Concalves Ferreira et al., 1977).

Human consumption represents about 90% of potato use; and the remaining 10% are mainly culled small potatoes used for feeding on small family farms.

Potatoes make several important contributions to the Portuguese diet; in addition to their energy contribution, they are an essential source of proteins and vitamin C for peasants who consume little milk and citrus. Portuguese nutritionists advocate

Table 1. Portugal: Per capita consumption of selected foods[1/].

Food	Per capita consumption (kg/year) 1977 Whole country Lisbon	1980 Whole country Expected Recommended	1977-80 Rate of growth Expected Recommended
Milk and cheese	62.7 170.8	66.3 113.8	1.9 21.6
Meat	47.3	52.6 44.0	3.6 -2.4
Fish	32.1	35.4 37.3	2.8 8.3
Eggs	4.8	5.2 6.0	2.7 7.7
Total	84.2 115.7		
Fatty foods	25.9 35.4	31.0 19.5	6.46 -7.2
Cereals [1/]	125.6	126.8 126.8	0.3 0.3
Legumes (dry)	6.0	5.7 5.7	-1.7 -1.7
Sugar	28.8	30.8 20.4	2.3 -10.9
Total	160.4 128.1		
Vegetables	147.5 251.5	156.0 145.5	1.9 -0.5
Fruits	78.0	83.7 98.8	
Potatoes	100.0 72.3	93.3 102.4	-2.3 0.8

[1/] From Concalves - Ferreira, 1977 and 1978.
[2/] Edible portion of the plant

an increase in per capita consumption of potatoes of around 10% over the next decade.

Potatoes should represent the following contribution in the portuguese diet: calories 7.5%; proteins 14.7%; carbohydrates 10.8%; calcium 1.4%; iron 0.18% vitamine B_1 6.8; vitamine B_2 6.5%; vitamine PP 14.9%; vitamine C 8.7%.

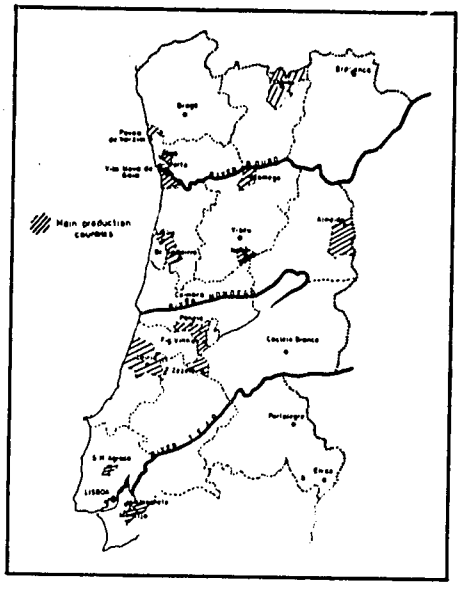
Production for processing is very recent and accounts for less than 1% of total production (This compared with about 10% in EEC).

Geography

The Northern areas of Portugal produce about two-thirds of the country's potatoes (Figure 1).

Potatoes are traditionally produced in this area for three reasons: summer is not so warm as in central and southern Portugal and nights are always cool; there is a favorable Atlantic influence in the rainfall pattern without drought in mid-summer (which is typical of the Mediterranean climate); the wetter climate enables forage production for dairy cattle, which, in turn provides farmyard manure and for the potato crop.

About half the Northern production is produced on deep coastal soils with high

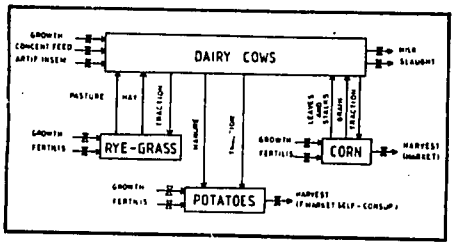


organic-content. Good soils and mild climate produce high yields.

Climatic conditions in the Northern coastal areas are favorable in relation to some significant temperature values for potato growth and development (Sands and Hackett, 1979). The year has eight to ten months with very suitable conditions for high potato yields: long frost-free period, moderate summer temperatures and good thermoperiodic balance.

Agricultural systems

The dominant agricultural system of the Northern coastal areas is represented (Figure 2). It is commercially oriented with a small amount of home consumption.



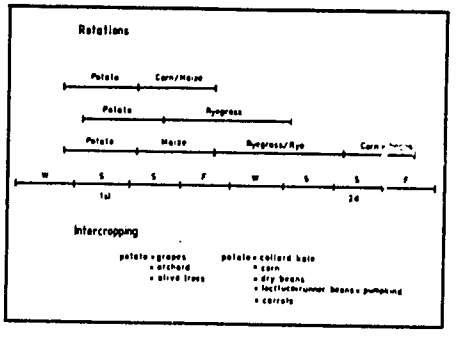
The production system is characterized by low capital intensity and use of family labour. The agrarian system is based on private ownership of small farms generally with less than 1 ha composed of an average of several plots (Viana and Barrocas, 1977). The average is 2 cows on these very small farms (Instituto Nacional de Estatistica, 1979). Tenancy is common and most of the farmers are illiterate. Manual labor in seed bed preparation, planting, and harvest requires 2,265 man hr/ha.

This can be reduced to 837 hr/ha by mechanical plowing and digging by animal power and to 584 hr by mechanical digging. Complete mechanization requires only 345 hrs hr/ha. (Lourenco and Alvez, 1968; Peinheiro and Portas, 1980). Dairy cows are still the main a source of traction.

Potatoes and maize are the cash crops and with milk, the main source of income. Potatoes go as a fresh market crop. This is in sharp contrast with milk of the Northern coast which is the main source of the country's dehydrated milk.

The potato cropping system is based on maintenance of a high level of soil fertility with farmyard manure before potatoes and maize.

Potatoes have long been recommended as a rotation crop because of the additions of large amounts of farmyard manure and the physical benefits to the soil from hand cultivation and digging. But the rotations apply to only a part of the farms, the remaining being mainly in forage crops (Figure 3).



Social changes and their consequences for potato production.

The system is rapidly changing as emigration, hard working conditions, and low labour productivity cause young people to leave the farms. Only the strong ancient tradition, the special situation of potatoes in the cropping system which can not easily be substituted (only peas have a similar cropping cycle); and lack of adequate social security for aged farmers maintains the agricultural systems as well as potato production in degradated conditions. Evolution is certain to take place resulting in modernization.

In fact, lowering population pressure would allow expansion of average farm size thus enabling mechanization and an increasing the number of diary cows per farm.

The northern coastal areas are in a better position for this challenge as yields at least double those of the interior mountains (Silva and Souto, 1981). But they lack storage infrastructure. In addition cooperatives, which dominate the marketing of milk are not present in the potato marketing, leaving small farmers completely dependent upon private marketing agents.

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POTATO WART DISEASE - A POTENTIAL THREAT TO POTATO PRODUCTION

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The fungus causing potato wart disease, Synchytrium endobioticum, first described in 1896, is one of two major soil-borne potato pathogens which has achieved worldwide distribution in the last 100 years. Excluding late blight, no other potato disease has evoked as much concern amongst growers. Because of wart, restrictive legislation has been introduced which is only matched by that for controlling contagious human and animal diseases.

Strict quarantine regulations to control wart govern import of potatoes into many countries (as yet) free of disease and regulate sale, movement, and planting of potatoes within infested countries. Thus, international and local trade have been affected.

This paper describes measures that have been successful in controlling wart disease in some countries but not in others, and conclusions to be drawn.

Origin and Spread

Potato wart brought from South America to Europe during the second half of the 19th century was possibly associated with great interest in potato breeding following the famine of the 1840's.

Wart has since spread to North America, northern, eastern and central Europe, South Africa, India, Nepal, New Zealand, Falkland Islands, and probably back to South America, - Uruguay, and Chile. Worldwide spread occurred as trade in seed and table potatoes intensified during late 19th and early 20th Century. A number of high yielding varieties, all of which were susceptible to European race 1 (Dahlem) became extremely popular, e.g. Up-to-date Epicure, King Edward, Bintje, President, Magnum Bonum, Eersteling.

Wart disease in North America

Following discovery of wart in Newfoundland in 1909, legislation was introduced in both Canada and the United States controlling the import of potatoes from areas where the disease occurred.

Wart has never become established in main-

land Canada, hence quarantine successfully prevented its spread from the island of Newfoundland.

Wart reported in 1918 in the United States (Pennsylvania, West Virginia, and Maryland) was possibly introduced from Europe around 1911. Internal quarantine measures prevented spread from this largely non-farming area. A clean-up program utilizing resistant varieties and the chemical sterilization of infested soils steadily reduced incidence until the area is now regarded as free of infection.

The disease in Europe

Gough in England (1909-10) was the first to recognise varietal differences in susceptibility. Spread of the disease was largely halted in the British Isles through use of resistant varieties, and a prohibition on susceptible varieties so that today the disease is only reported from gardens and small plots. The seed potato industry and certified seed assured seed guaranteed as true to name of resistant varieties. Similar legislation was introduced in other European countries. Here again the threat has been diminished but outbreaks of the disease occur in non-commercial farming areas.

Wart and Newfoundland

Legislation to prevent growing susceptible varieties and to impose internal quarantine was introduced in 1916, but necessary enforcement did not occur, because of small scale subsistance type farming in hundreds of communities scattered along thousands of miles of coast. Most all soils in the island became heavily infested. Due to shortage of cultivatable land, hence a lack of crop rotation, and the exchange of "seed" between neighbours, almost all soils in the island became heavily infested. Until Newfoundland became part of Canada in 1949 seed potato production was never initiated and the only new seed was obtained from the British Isles.

Races of potato wart

Following the discovery of the "new" German races in 1942, more than one race of the pathogen has been reported from several other countries, Czechoslovakia, Russia (Carpathian zone), the Indian subcontinent) - (India, Nepal), Newfoundland, and Peru.

Occurrence of several races seems to be associated with small scale subsistence, or part-time potato production. Conditions under which race differentiation may occur are as follows:

1. High levels of inoculum present in the soil as a result of growing race 1 susceptible varieties, and suitable climatic conditions for maximum disease development.
2. Frequent use of growers' own seed.
3. Lack of crop rotation.
4. Common practice of growing mixtures of varieties.
5. Wide fluctuation between day and night temperatures.

Some workers believe that weakly resistant varieties (i.e. those varieties whose sprouts react with late necrosis following artificial inoculation) may act as bridges in racial development.

In some countries in Europe, e.g. Ireland, England, no race differentiation has occurred, but in the Federal Republic of Germany between 1945 and in 1979 race 1 occurred in less than 1% of all reported outbreaks.

In Newfoundland, European race 1 occurs in only a few locations whereas races similar to 2 and 6 are widespread. Little information is available on whether several races may exist in the one field, or on the length of time which elapses between the occurrence of a new race and its complete replacement of the existing race.

Breeding for resistance

While the genetic basis for resistance to race 1 is not completely clear, it is apparent that only a few genes are involved.

Breeding material having resistance to other races is more limited than that for race 1. The Dutch red varieties derived from Rode Star, and varieties derived from the German selection BRA 9089 show resistance as well as Saphir (whose resistance may be from S. acaule) and varieties derived from certain andigena lines, e.g. Imandra and Fortuna. Most of those selections are also resistant to race 1. Ora is resistant to all known 16 European races but is susceptible to some Peruvian isolates. Four wart resistant cultivars introduced to Newfoundland have diverse genetic background: Pink Pearl - resistance derived from Ultimus; Anson, Mirton Pearl - resistance derived from Ora; Blue Mac - resistance derived from andigena CPC 1673.

Climatic conditions and disease development

The occurrence of wart in some countries or in restricted localities suggests that specific conditions are necessary for disease. Growing seasons with temperatures above 22°C (72°F) favor potato infection. Free soil moisture is essential for infection and most severe infections occur when soil moisture is abundant throughout the growing season. Hence, wart in many tropical or sub-tropical areas appears unlikely. Where suitable climatic conditions exist, preventing introduction of wart through quarantine regulations must remain a high priority. Today, introduction of wart disease via commercial movement of potatoes or plants seems to be much less likely than accidental introduction by tourists, farmer exchange groups, or even botanical collecting expeditions.

Conclusion

Providing that the quality of seed and table potatoes being produced by exporting countries remains at the present high level of phytosanitary health, there is little danger of potato wart disease being introduced, through commercial channels, into other countries.

In those countries where wart disease does occur, past experience indicates that a combination of (1) vigorously enforced internal quarantine regulations, (2) use of resistant cultivars, (3) grower education and (4) soil sterilization (where practical) will effectively reduce the significance of this disease.

Largely untapped sources of resistance to the potato wart disease pathogen exist in the andigena collection of germ plasm at the International Potato Center and this could be readily used in the development of new cultivars with resistance to one or more races of the pathogen.

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ACTION OF MINERAL OILS IN PROTECTION FROM POTATO VIRUS Y

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The inhibiting action of mineral oils on transmission of non-persistent viruses has been known for a long time, but its mechanism is not yet understood. These mineral oils have been used for a few years in France for potato seed production in order to reduce potato virus Y (PVY) levels. Positive results were obtained, however, there are some doubts as to the value of this method. We tried to get a better un-

derstanding of the phenomenon by studying in the laboratory, the inhibition effect of paraffinic oil on transmission of PVY (strain Yo) by Myzus persicae Sulz.

Action of mineral oil during stages of PVY transmission by Myzus persicae

Oil emulsion (3% in water) was applied to leaves of one stem shoots of potato (var. Bintje) during stages of transmission by aphids. Virus detection using ELISA tests in inoculated plants gave the following results (Table 1):

Oil has a considerable effect throughout the transmission cycle (up to 96% inhibition of transmission) in spite of the low quantity of applied active substance (110 to 138 µl mineral oil per plant).

Oil application after virus inoculation in the test plant has no effect. The oil-aphid contact must occur prior to arrival of the infections aphid on the healthy plant.

By contrast, oil-aphid contact, prior to virus acquisition by the insect, produces inhibition of transmission.

It seems that oil acts on virus transmission (virus-vector relationship) rather than directly on the virus or the plant.

The inhibiting effect occurs mainly during virus acquisition.

If the vector is placed for one minute on a healthy intermediate plant. The effect is maintained although to a lesser extent, upon inoculation of test plant with oil.

Table 1. Effect of mineral oil on stages of the transmission cycle.

Time of oil treatment	Virus infection 1/	Inhibition in relation to control %
Before acquisition		
control	50	
treatment	9.4**	81
During acquisition		
control	75	
treatment	3.1***	96
On intermediate plant		
control	66	
treated	6.2**	91
During inoculation		
control	69	
treated	31*	55
After inoculation		
control	81	
treated	78	--
During acquisition and inoculation		
control	69	
treated	6.2***	90

1/ Percent virus infected plants in relation to control. Data from 4 experiments of 8 plants each.
*** very highly significant of by Student-Fischer t test.
** highly significant
* significant

Acquisition of virus through membrane in presence of oil.

We adapted for our study a method of virus Y acquisition by M. persicae through a parafilm membrane and transmission was then tested on plants. It was confirmed that the oil solution added to the plant extract in a medium including sucrose 15%, methionine 0.08% at pH 6.5 had an inhibiting effect on acquisition which was highly significant with 4 replicate experiments, (61.3% acquisition and eventual transmission without oil as compared to 16.1% transmission with 2% oil).

However these trials did differentiate between the two hypothesis presently proposed, i.e. action on virus vector relationship, or change in aphid behaviour (fertility, nutrition). A method for studying individual fertility of aphids has been developed. Reproduction of these insects placed on oiled leaves decreased by approximately 40% as compared to control.

In 6 trials an average of 20.5 nymphs developed on the untreated leaves and only 12.3 on the oil treated leaves. These differences were highly significant statistically.

As oils have no aphicide effect, this decrease in reproduction does not account for the inhibiting effect, but it could be due to a change in nutritional behaviour of aphids. Measurements of feeding behaviour of aphids in the presence of oils are being performed. The first results obtained suggest a change in nutritional behaviour as influenced by oil.

Oil diffusion in the plant.

Field experiments confirmed that the protective effect of treatment with small amount of mineral oils can last for over a week. During this period, plants continue to grow and develop new non treated leaves, on which aphids can feed. It was then suggested that oil diffusion in the plant may produce a systemic effect.

Experiments were conducted with a small amount (100 µl) of basic oil, not in emulsion. Hexadecane C^{14}, a component of paraffinic oils, was mixed with mineral oil. Preliminary chromatographic study showed a similar migration of this perfectly homogenous mixture. Hexadecane, a satured paraffinic oil, is known not to be degraded by plants. Labelled oil was applied to the surface of one potato leaf. Migration and distribution in the plant, were followed by radioactivity (Table 2):

Table 2. Oil distribution in plant organs, as a percentage of total migrated radioactivity.

Radioactivity	Time after application of labelled oil 1/				
	5	10	15	20	25
apical portion	11.7	2.0	4.8	28.9	25.5
leaves	16.3	27.9	44.7	28.2	12.3
roots	1.9	30.9	17.8	7.4	38.8
stems	70.1	39.2	31.1	34.4	23.4
upward migration	23.75	39.2	34.1	49.7	34.5
downward migration	6.15	21.6	34.8	15.9	42.1

1/ 5 µ C^{14} labelled oil on leaf two.

- The oil penetrated and migrated in the plant and was present up to 21% 24 hours after application, and 13% after 5 days. This percentage decreased in time and eventually seemed to stabilize. The oil was demonstrated in all plant organs, including flowers and tubers. Toxicity which may have resulted must be emphasized.
- The stem seems to act as a place for accumulation and distribution of oil in the plant.
- Migration is mainly ascending. Newly formed young leaves seem to exert a strong attraction on oil rising to the apex.
- The oil passed from the plant to the earth. It is suspected that oil eradication by roots might occur from a given level of oil accumulation in these roots. As mineral oils are located exclusively outside of the cells, we could think that oil diffusion is related to capillarity strength and adhesion in the intercellular system.

Action of migrated oil on PVY transmission by M. persicae

Transmission experiments confirmed that:

Oil deposited on the surface of a treated leaf protected for approximately 10 days.

Oil that migrated and localized in the plant inhibited vector transmission of PVY for 5 to 6 days.

Inhibition of PVY transmission by M. persicae is apparently due to the contact between aphids and the oil film on the leaf surface as well as with oil located in the intercellular spaces.

Conclusion

Two major hypotheses have been considered to account for oil action mechanism. Oil could act, by modifying the feeding behaviour of aphids and hence their ability to transmit PVY or by modifying vector-virus relationships, in particular, by occupying sites of virus fixation on the insect.

The above results seem to indicate that the two hypotheses are not necessarily contradictory. It is assumed that oils have a multifactor effect.

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APPROACHES TO INTEGRATED CONTROL OF PHTHORIMAEA OPERCULELLA

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Summary

A long-term goal of this study is to develop methods that can serve as components of an integrated control program minimizing or even excluding the use of insecticides for control of potato tuber moth, Phthorimaea operculella under field and storage conditions. Host plant resistance, sex pheromones, and vegetable oils are emphasized. A general outline of observations and results presented for each of these methods indicates that development of an integrated control program with minimum use of insecticides is possible.

Introduction

Several approaches are available for the development of an integrated pest management system for P. operculella. In integrated approach combining cultural, physical, chemical and biological methods appears the most promising means of controlling this pest (Haines, 1977). Cultural and physical control measures include proper hilling up, adequate irrigation, pre-storage tuber selection, mothproofing of stores, and good storage sanitation. Several insecticides have been successfully used in both pre- and postharvest treatments but high levels of resistance to many of them have been encountered in several developing countries. A long-term goal, therefore, is to develop methods that can serve as elements in a total integrated control program that would minimize or even exclude the use of insecticides. Therefore it is of importance to develop methods of control to lower the general level of infestation. Consequently the main objectives to attain this goal were; to use host plant resistance, sex pheromones, and to discover whether vegetable oils which are locally available can be used in storage to control this pest.

Material and methods

Resistance: The main objectives include, development of simple, efficient and reliable screening methods to identify sources of resistance, which can be used for breeding resistance into high-yielding, lowland, tropic-adapted cultivars. Between 1979 and 1982, some 6,000 accessions of primitive cultivars and 452 accessions of wild potato species were screened. Screening methods were developed at three levels: in the laboratory using controlled infestation, and in the field or during storage using natural moth populations. Detailed description of these methods are presented (Raman and Palacios, 1982; Raman, 1982). Utilizing natural infestation in storages is the simplest way of testing. This method is used to screen large numbers of accessions for major differences in tuber damage. Tubers of accessions are placed in paper bags, kept open for tuber moth entry in a randomized complete block design and assessed for tuber damage at regular intervals. Due to an irregular distribution of moths a relative large number of replicates is necessary to detect significant differences. Susceptible cultivars Atzimba and DTO 33 were included in all tests as checks. In the laboratory, tubers were infested artificially in plastic cages as described by Raman and Palacios (1982) with first instar larvae reared in the laboratory. Larval densities used in screening trials are similar to those of infestations found in storage. Dependence on an adequate supply of insects made this kind of a test feasible only to test small numbers of accessions which were selected in storage or field screening trials. This test also made feasible the determination of the mechanism of resistance.

Sex pheromones: The discovery of potent sex pheromones produced by P. operculella females as an attractant for males (Roelofs et al., 1975) have opened the way for their use in selective control of this pest. The performance of two different formulations of P. operculella were studied under field conditions and seasonal moth population trends were related to tuber infestations at harvest (Raman, 1982). Studies on direct control with sex pheromones have been conducted using the mass-trapping approach wherein males are lured into simple, easy to construct funnel traps into which small quantity of carbaryl dust was placed. Males attracted to lures suspended in such traps are eliminated from the reproduction process. Trapping studies were conducted during 1980 and 1981 at CIP's experimental field station near Lima. In initial studies a water trap described by (Bacon et al., 1976) was used, later a simple funnel trap was found to be as effective as the water trap. This trap has great potential in mass trapping and needs no servicing.

Vegetable oils: Work conducted elsewhere has indicated that oils can be used to control bruchid pests occurring on stored legumes and grains. No work has been done to study if a similar phenomenon occurs for potato tuber moth control. Several vegetable oils: peanut oil, corn oil, vegetable oil were tested in storage to study their potential in terms of degree and duration of control of the pest and satisfactory quality and viability of treated tubers. By determining how the oil works it is hoped that it might be possible to indicate its most efficient use, and also other situations in which it could be used most beneficially.

Results and discussion

Resistance to tuber moth has not been previously a major potato research objective. To date 24 primitive and 21 wild potato accessions were identified as highly resistant. These accessions were resistant to both tuber damage and successful pupation and are now being used in breeding resistance into potentially high-yielding potato varieties adapted to lowland tropics. Resistance is attributed to antibiosis. No resistance was found in the primitive cultivars of S. juzepczukii Buk. and S. curtilobum Juz. et Buk. that are generally regarded as containing high amounts of solanine. The total glycoalkaloid (TGA) levels for S. juzepczukii and S. curtilobum have been reported as 24.86 and 38.66 mg/100 g (fresh weight), respectively (Schmiediche, 1977). Therefore, TGA might not be involved in the resistance found in the primitive cultivars of S. andigena Juz. et Buk. and S. stenotomun Juz. et Buk. whose TGA levels are at least 5 times lesser than the bitter andean potatoes. Experiments on oviposition indicated that pure extracts of 35% solanine and 64% chaconine at 5, 10, 50 and 250 mg/100 mls of water had no effect on oviposition. Results of inheritance studies indicated that resistance was mostly dominant and controlled by a few major genes. In one reciprocal cross, clear cytoplasmic effects on the resistance were observed. Although the three resistant diploids did not produce 2n pollen, one of them produced 2n eggs. Thus, the resistance of the diploid was transferred into the 4x level through 2x - 4x crosses. About one third of the tetraploid progeny from the crosses showed resistance. The inheritance pattern and the relative high transmission rate of resistance to the 4x level from the 2x level, in addition to the discovery of new sources of resistance in diploid and cultivated germ plasm, suggests that breeding for resistance should not be difficult.

The formulation trans-4, cis-7- tridecadien-1-ol acetate (PTM 1) + trans-4, cis-7, cis-10, tridecatrien-1-ol acetate (PTM 2) was more attractive than PTM 1 only. These formulations remained effective for one year in the field. Apart from studies in monitoring, potential of these pheromones in mass-trapping for direct control has been established. Comparisons were made of water traps baited with virgin female tuber moths not surrounded by synthetic pheromone and of female baited water traps that were surrounded by 8 traps (one trap per 100 square meters) using the synthetic pheromone PTM 1 + 2 as a lure. The presence of synthetic pheromones reduced the catch in the surrounded water pan traps baited with females by 97 percent. Tuber damage of clone DTO 33 at this trap density could be reduced 34 percent with the aid of pheromones. In storage, utilizing small storage units, 90 percent of all males could be captured within 4 days after emergence. Damage to tubers was reduced by more than 50 percent using pheromone traps. The funnel trap described earlier is currently being utilized in mass trapping trials both under field and storage conditions.

Effect of various vegetable oils on the eggs of potato tuber moth was studied initially in the laboratory. When oil was applied to eggs laid on filter paper, the development of the eggs was usually arrested. The oil either caused abortion of the embryo, or else produced no visible change but prevented embryogenesis. The oil may either block the micropyle or enter the air-filled space beneath the chorion and destroy the "plastron". Such effects have been demonstrated by others working with bruchid insect pests attacking stored legume seeds. In storage undiluted oils were highly phytotoxic to tubers leading to rotting and death of sprouts. Our experiments have identified that 1% vegetable oil is non-phytotoxic and provides adequate protection if applied once every two weeks in storage. Our results suggest that the development of an integrated control program with minimum or no use of insecticides for controlling this pest is possible. While some components of an integrated control approach against potato tuber moth have been conclusively identified, work on other components is still in progress.

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POTENTIAL OF PHYSICAL RESISTANCE MECHANISMS FOR THE CONTROL OF MAJOR INSECT VIRUS VECTORS OF POTATO

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Summary

Glandular pubescence, a unique mechanism of defense against insects, is currently being utilized in potato breeding for the control of Myzus persicae (Sulzer) the major aphid vector of potato leafroll virus (PLRV). Results on rapid screening techniques and the degree of aphid suppression in crosses made between glandular haired species vs. cultivated tetraploids are presented. Future research on utilization of this resistance mechanism involves stabilizing genes for this mechanism in CIP breeding populations and studying the effect of glandular hairs on virus spread.

Introduction

The potato, Solanum tuberosum L., the fourth most important food plant of man, is subject to major losses by virus diseases. Most viruses are transmitted by insects, therefore, they remain one of the major obstacles to the successful cultivation of the potato crop. Genetic resistance to insects has in the past received little attention in potato breeding. Experiments at CIP, and elsewhere have conclusively demonstrated that glandular hairs on the foliage of S. berthaultii, S. polyadenium and S. tarijense protect the plant against foliage feeding insects and spider mite infestation by physically trapping and immobilizing them. The objective of this project is to breed potato populations with high densities of glandular hairs.

Materials and methods

For screening purposes densities of 4 Lobe (Type A) and simple sticky hairs (Type B) are determined by excising the fully-expanded terminal leaflet at the pre-bloom stage. A small (1 cm) strip is cut from the center of each leaflet at 90° angle to the mid-vein. Numbers of glandular hairs on lower leaflet surface are counted at 60X in a 8.37 mm^2 area. This procedure is time consuming and up to a maximum of 200 leaf samples can be evaluated in one day. Therefore, it was essential to develop a simple rapid screening method which could be used in the field.

Such a method based on the enzymes in glandular trichomes which oxidize simple phenols, namely polyphenol oxidase (PPO) and peroxidase (PO), has been developed to aid breeders in selecting (Anon, 1980). Using a cotton swab dampened in 4.8% catechol and wiping the epidermis on the lower leaf surface of the terminal leaflet of the third leaf from the top, a color reaction was obtained when glandular hairs (Type A and B) were present. A 1-4 color code was used to determine the relationship between color on the cotton swab vs densities of glandular hairs (A and B) in F_2 progeny of a cross between S. berthaultii x S. phureja. The Pantone matching system (Sun Chem. Corp. USA) was used to index the color.

Results and discussion

Mean number of glandular hairs, type A and B per mm^2 were positively correlated with color intensity (r=0.72, y=1.83 + 3.10X). This method would, therefore, enable rapid screening for glandular hairs without initial microscopic examination of excised leaves. Selections made through this test should be finally evaluated using a microscope at 60x magnification. Our results and those of Cornell University indicate that 4 lobed hairs (Type A) alone are not effective in reducing aphid populations, it is therefore essential that selection is made on both types of hairs. Stabilizing simple sticky hairs (Type B) will be difficult as a strong dominant suppressor gene has been found in S. tuberosum and S. phureja. The interploidy 4x - 2x crosses to transfer the glandular hairs of S. berthaultii to S. tuberosum c.v. Pentland crown were successful due to 2^n pollen produced by S. berthaultii. F_2 progeny of this 4x - 2x cross were evaluated and selected for high densities of glandular hairs (Table 1). All crosses using S. berthaultii as the female parent have been unsuccessful. To facilitate making interspecific and interploidy crosses, several plants from the sibmated family of S. berthaultii (P1 265858) and hybrids between these sibs and S. phureja have been selected for high frequency of 2^n pollen production and aphid resistance. F_2 progeny of S. berthaultii x S. phureja selected for high densities of glandular hairs, supported very few aphids (1-6/-plant). In comparison, cultivar Renacimiento which has very few glandular hairs of Type A supported higher populations of M. persicae (32 aphids/plant) at 12 days after infestation. The retarded population development of important insect vectors eg. M. persicae, using this mechanism would allow less frequent application of insecticides.

Acknowledgment

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Table 1. Twelve interspecific crosses of S. berthaultii x S. tuberosum (Pentland Crown) evaluated and selected in the F_2 generation.

Parents	Glandular trichome density (Number)	
	simple	4 lobed
Pentland	2.00	30.50
Crown X	11.00	22.00
S. berthaultii	18.50	6.60
"	28.33	26.66
"	42.66	17.66
"	46.80	9.40
"	56.00	10.00
"	58.25	7.50
"	60.00	12.00
"	69.50	34.00
"	90.30	6.60
"	99.00	24.00

1/ Number of hairs in area 8.37 mm^2.

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VARIETY DEVELOPMENT PROGRAM ON POTATO IN THE PHILIPPINES

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Historical background

Variety development on white potato through varietal and clonal selection was recorded in the Philippines as early as 1916 at the University of the Philippines, College of Agriculture. These selections however, were limited to varieties and clones imported from foreign countries. The result of these trials was adopted by some farmers in the highlands of Benguet which became the traditional potato growing area of the country.

Preliminary work on variety trials was later revived in the 1950's through the efforts of Dr. Teodoro G. Cadiz and some thesis students. Results obtained indicate that production of white potato outside the cool climates of Benguet provided a very slim margin between profit and loss.

In the mid 1950's, Balaoing of the Bureau of Plant Industry also worked intensively on variety trials and degeneration rate of imported seeds in Baguio and stated among other things that "no amount of improved cultural practices could increase production if the planting materials are highly degenerated or virus infected".

Results of these initial works plus the contribution of the International Potato Center (CIP) and the German Agency for Technical Assistance (GTZ) were used as benchmark information in the formulation of the breeding component of the present Philippine Potato Program.

Present situation

The Philippines is faced with the problem of rapid population growth and malnutrition. It is estimated that if the present growth rate is maintained, the population of the country will be doubled by the year 2000. On the other hand, total arable land can increase only by no more than 15% in the same time frame (Rasco, 1978). Increasing production per unit area would then be the main solution.

White potato with its known potentials can help solve this problem. It is the world's major crop in terms of calorie production per unit area per day. It ranks second to soybean in terms of protein production per unit area (FEDS, 1970). In the Philippines, potato is also considered a high ranking money-making crop per unit area and per unit man-hour of labor. A recent survey made by the National Economic Development Authority (NEDA) indicates that table potato farmers' net income ranges from P6,000 to P15,000 per hectare per crop season. Since the crop can potentially be grown three times a year, potato production can substantially improve the living standard of the Filipino farmers and improve the malnutrition problem of the country.

If the total potential areas for potato production in the high and mid-elevation areas (per NFAC survey, about 45,000 hectares) will be utilized, then production can increase considerably. The cultivation of the potential areas will not in any way reduce the area used for other crops since these areas are not presently utilized.

Unfortunately, the limited adaptability of the presently available varieties makes this expansion impossible. Present varieties do not tuberize satisfactorily in the warm areas and they easily succumb to pests and diseases against which they do not have resistance. To make expansion possible, potato varieties suited to the mid-elevation conditions (ultimately, to the low elevations) would have to be developed.

Objectives of the Philippine Potato Breeding Program

Short Term:

Identify organizations involved in variety evaluation and develop a system of coordinating them;

Establish a working relationship with CIP, GTZ and other international agencies involved in potato breeding.

Organize expended varietal development program.

Long Term:

To develop varieties that are high yielding, pest resistant and truly adapted under Philippine conditions.

To develop varieties for high and mid-elevation and eventually for low-elevation areas.

Strategy of implementing the Philippine Potato Breeding Program

The flow of materials and testing scheme in the Philippine Potato Program through the Institute of Plant Breeding variety development program is shown (Figure 1). At this time, however, no controlled crosses will be made. Varietal evaluation will be concentrated on germplasm available from CIP, US, Europe, and other countries.

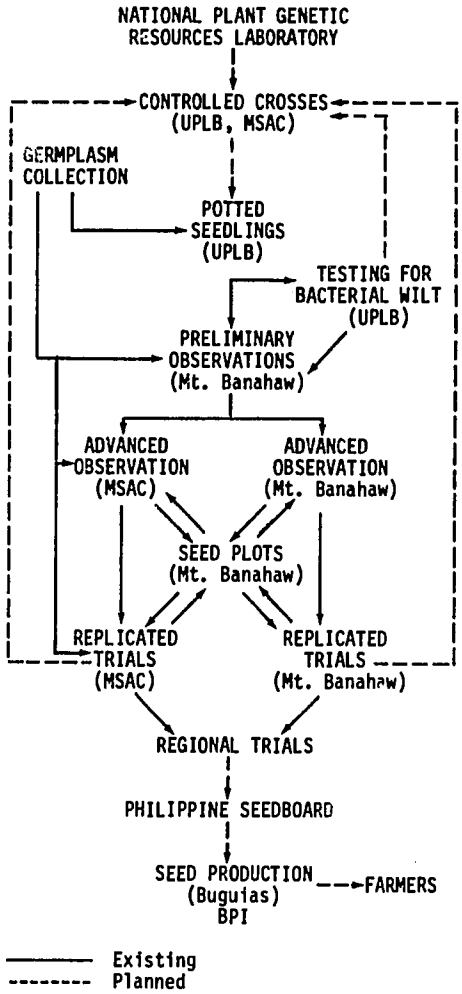

Figure 1. Flow of materials in the potato program. (After Rasco, 1980).

The breeding program, is embodied in five projects, namely:

a) Germplasm introduction, preliminary and advanced evaluation at high elevation;
b) Supportive research on the techniques for controlled pollination with reference to temperature and daylength;
c) Refinements on the use of true seed with reference to transplanting procedures;
d) Development of varieties for mid-elevation (subsequently for low-elevation) areas;
e) Breeding or selection for resistance to various pest and diseases.

Highlights of accomplishments

Genetic materials totalling 477 packets of true potato seeds (TPS), 66 tuber families, 273 clones and 72 commercial varieties were received from the United States, Canada, Australia and the CIP (thru the Regional Representative, Region 7); from AVRDC in Taiwan; The Netherlands; Germany; Kenya; England; India; Peoples Republic of China; New Zealand; Papau, New Guinea; Indonesia; and Belgium.

Results obtained from trials at high and medium elevations are shown (Table 1).

The project conducted preliminary tests of 26,000 potted seedlings, 11,000 seedling hills, 600 first 4's, 154 first 10's and observational trial entries since 1978. From this effort, there are now 1943 surviving clones at different stages of development. Promising selections have been included in the regional test.

Table 1. Performance of white potato varieties under different conditions[1/] (After Rasco, 1980).

Variety and number of trials ( ) Marketable yield (t/ha)	Remarks
High elevation, dry season clean seed	
Jaerla (6) 29.4	Good storage quality; medium size tubers
Siro (4) 29.4	Late blight resistant; medium storage quality
Baraka (3) 27.9	Tends to oversize; poor storage quality
Red Pontiac (5) 27.1	Red skin preferred by consumers; medium storage quality; late blight susceptible
Cosima (7) 26.1	Excellent storage quality; late blight moderately resistant
High elevation, dry season "farmers seed"	
Greta (3) 20.2	Late blight moderately resistant; medium storage quality
Conchita (4) 17.5	Late blight resistant; medium storage quality
Cosima (2) 16.9	
TA-37 (2) 16.3	Late blight moderately susceptible; small tubers; early tuberization.
High elevation, wet season "clean seed"	
5797-9 (1) 22.6	Susceptible good tuber appearance; late blight susceptible
Kennebec (1) 20.3	Late blight resistant; poor storage quality; tends to crack
5805-14 (1) 19.8	Round tubers, deep eyes; poor storage quality; late blight moderately susceptible
TA-4 (1) 19.5	Late blight moderately resistant; small tubers
Medium elevation, dry season "farmers seed"	
5805-14 (3) 15.0	
Up-to-date(5) 13.0	Round tubers; poor storage quality
Cosima (7) 12.0	
A. Banner (4) 11.5	Late blight susceptible; growth cracks
Coliban (4) 11.5	Good appearance; medium storage; late blight susceptible
Medium elevation, wet season "farmers seed"	
Red Pontiac (3) 11.6	
A. Banner (2) 10.8	
Roslyn Gucha(4) 10.2	Medium size tubers; poor keeping quality
Kennebec (4) 9.9	

[1/] Based on data from UPLB, BPI, MSAC and CIP.

Self assessment of the Program

At the moment, we are stretching the genetic variability of potato when we intend to take it down to lower elevations.

In other places where potato is commercially grown, temperatures may even be higher than in the Philippines during mid-season but it is always mild or cold at the beginning and at the end of the season. Temperature and daylength adaptation have always been a problem with introduced materials.

There are various biological constraints in the Philippines that the potato has never been exposed to before, such as bacterial wilt and thrips. The frequency of genes for resistance to these constraints is generally low in the existing world germplasm. Bacterial wilt resistance is not known to exist in the commercial potato (Solanum tuberosum) and genes for resistance are found only to S. phureja and S. sparsipilum which do not readily cross to tuberosum even under the most favorable environments. In the case of thrips, no other country in the world seems to have a serious problem with the pest and therefore we may have to breed for resistance on our own.

Since we have started the breeding program 3 years ago, we have not made a single controlled pollination. Somehow, even clones that flower and set fruit naturally in the field, fail to do so under greenhouse conditions. It is therefore necessary to develop appropriate technology for our own situation. In the meantime, we will have to rely on imported hybrid seeds for our testing program and it is very evident that the fate of our breeding program will to a significant extent be decided in Peru, United States, Mexico, Australia, The Netherlands and other countries that supply us with germplasm. We are still fortunate, however, because these countries are also interested in many of the problems that we are working on.

Other constraints that beset our breeding program are inadequate financial support and lack of trained manpower. At the moment, each of the agencies involved in the national programs pursue a certain aspect of the work at their own expense but a more efficient coordinated effort is still wanting. We are working on this and see bright prospects in 1982 and later.

Projected plans

The breeding program will definitely continue at the present level, with some modifications to avoid past failures. However, we will expand the scope of our advanced and regional trials.

Development of TPS (true potato seed) will gradually get a large share of our resources in the event that our hybridization activities become possible.

On the other hand, we also hope to receive CIP's continued support by way of a steady supply of CIP's advanced lines/clones for inclusion in our testing and evaluation program.

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SOME COMPONENTS OF BACTERIAL WILT (PSEUDOMONAS SOLANACEARUM) MANAGEMENT AMONG TROPICAL POTATO GROWERS IN SOUTHERN PHILIPPINES

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Summary

The paper highlights some interesting management practices to reduce incidence and damage by bacterial wilt, which at present is the most serious disease of potato in the region. The management practices are described along with some background information on how they were evolved. Possible reasons on how and why these practices effect reduction of losses from the disease are discussed. Implications of these practices in evolving viable methods to minimize bacterial wilt in the region are presented.

Introduction

Approximately 65% of the land area planted to potatoes in the Philippines is in Benguet and Mountain Provinces in the Northern island of Luzon. Here the climate is temperate and cool in contrast to the strictly tropical environment of the adjacent lowlands. The remaining 35% is found elsewhere in the country although the bulk (25%) is found in the southern island of Mindanao, specifically in the provinces of Bukidnon and Misamis Oriental. The climate in this area is basically tropical with annual precipitation averaging 750 mm. Temperature ranges from 20°C to 30°C and humidity varies from 80% to 95%. Rainfall distribution is more evenly distributed compared with the distinct dry and wet seasons of Luzon.

Pest management practices; discussion and implications

After visiting with and having dialogues with some potato farmers in Intavas, Bukidnon Province in September 1981, it became clear that they have evolved some practical and meaningful management practices, which, after years of experience and keen observations, assured them of constant, though not necessarily high yields. It was apparent that in one way or the other, these practices contributed much in reducing risks from bacterial wilt, the disease they dread most.

These practices consist of the following:

Fallow rotation. The vast land still available permits the farmers to move from one site to another periodically. Ordinarily, no more than two plantings in sucession in the same site are practiced due to increased incidence of the disease.

Crop rotation. Many farmers routinely rotate potato with non-host crops like upland rice and corn. Following the non-host crops, weed vegetations are allowed to regenerate; alternatively another crop of potato is planted.

Planting in areas with good natural drainage. Most farmers avoid flat areas because wilt incidence is high. Instead they select sites with natural slope and excellent drainage resulting in minimal loss from bacterial wilt (Figure 1).

Use of resistant/tolerant varieties. The farmers plant varieties they claim to be "less affected" by wilt year after year. One such variety is called "Alpha".

Use of good seed. For the most part the farmers rely upon seed tubers produced elsewhere. These are produced in the isolated upper slopes (approximately 1200 m), which have conditions less favorable for the proliferation of various insect pests, pathogens, and disease vectors.

Figure 1. Field with natural slope is preferred because damage is less severe than in poorly drained fields.

The foregoing substantiate the need to appreciate the various factors which lead to successful development and subsequent dissemination of the wilt bacterium. To a great extent cultural/management practices which the growers found helpful in reducing losses from the disease relate to pathogen survival. Clearly the fallow period averaging two years is quite adequate to reduce inoculum to non-destructive levels. It is known that the bacterium can survive for much longer periods without adverse effects on its infectivity. Various factors including strain, soil texture and structure, soil moisture, solar radiation intensity, weeds and other flora as well as soil fauna, may help explain such discrepancies.

The use of corn and rice as rotation crops are not only logical but also practical. Although the bacterium has a number of primary hosts (tomato, eggplant, pepper, banana), corn and rice are not. Neither do cereals in general and potato have many other diseases as well as insect pests in common.

Planting in sites with natural slope certainly reduces predisposition to infection by the wilt pathogen. It is known that water is one of the most effective agents of bacterial dissemination. By planting in well-drained sites, unnecessarily long contacts of bacterium-laden water with susceptible tissues are minimized. Soaked tissues also become more succulent making them very prone to abrasion or other mechanical injuries; such injuries facilitate easy access of the organism to the susceptible tissues.

Normally after years of keen observation, a crop grower would know what crop or which variety of a given crop perform better under his farming practices. The case of "Alpha" variety which the growers in the region seem to prefer because of apparently better resistance to wilt is an example. It seems only logical that the potential of this variety should be explored to the maximum by using it in a planned breeding program, aimed at identifying "improved varieties" intended for cultivation under these farmers conditions.

The use of planting materials produced in isolated sites can not be over emphasized. That good, pest and disease-free planting materials should be used by any crop grower is fundamental to productive agriculture.

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EFFECTS OF POLYCULTURE (MIX CROPPING) ON THE INCIDENCE AND SEVERITY OF POTATO PESTS AND DISEASES

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Summary

Ravages by insect pests and diseases could become formidable challenges when potato (or any crop) is extended to non-traditional climates. At first it is imperative that immense resources should be directed in identifying cultivars that are climatologically adapted in the areas of intended introduction. Once this is accomplished, a thorough knowledge and appreciation of the existing cropping systems in these areas will reduce risks of damage by potential pests and pathogens.

Results of work on polyculture under three distinct agroecological conditions, and its pest-disease stabilizing properties are presented and discussed.

Introduction

Polyculture or mix cropping is a very conspicuous feature of traditional farming or peasant agriculture. The number of crop species in a field may vary from two to more than a dozen. Often, a crop species and/or variety predominates; others are planted in smaller patches. Various kinds of mix cropping are practiced. These differ in relation to the intimacy or contiguity of individual stands, relative times of planting, the duration of mixing and the spatial arrangements of the components of the mixture. (Litsinger and Moody, 1976; Brader, 1978; Soria, 1975).

The pest-stabilizing properties of crop species in mixtures is well known. These properties have been attributed to various causes including barrier, trapping, color and olfactory effects, microclimate modification, etc. (Buranday and Raros, 1975; Perrin, 1980; Nickel, 1972; Van Emden and Williams, 1974; Brader, 1979).

The subject of this paper is about the effects of polyculture (mix cropping) on pest and disease incidence and severity. More specifically, it deals with pest and disease situation on plots planted to sole crops of potato and row intercrop plots of potato and other crop species. Published literature on potato mix cropping and its effects on pests and pathogens is virtually nil. After querying backyard potato growers in Huancayo and Huanuco regions of Peru, where some potato mix cropping is practiced, the replies were almost invariably "our plants look better when grown as mixtures than when grown as sole crops". Subsequent conversations with colleagues working in the regions revealed that mix cropping involving potato and local crops is also practiced in Kenya, Rwanda, and Indonesia.

Material and methods

Mix cropping (row intercropping) experiments were conducted under three distinct agro-ecological conditions of San Ramon (800 m, mid-elevation tropics), Yurimaguas (180 m, lowland tropics), and La Molina (240 m, coastal desert), Peru in 1980-81. The San Ramon and Yurimaguas experiments were planted at the end of the rainy season whereas the La Molina experiment was planted during the winter season. The plants were grown as row intercrops and raised following recommended cultural and agronomic practices. To insure population build up and/or development and spread of naturally occurring diseases and pests, the plots were left unsprayed with insecticide or fungicide. Infestation/infection spread were monitored periodically and so was the occurrence of, and build-up of predators and parasites.

Results

San Ramon. No serious insect damage was observed. Late blight (Phythophthora infestans) was the most destructive disease. Differences in infection severity varied remarkably among some crop associations. Potato plants in the potato-sorghum intercrop were clearly the least affected. Potato plants in the sweet potato-potato, tomato-potato and sole potato plots were the most severely affected by the disease.

Yurimaguas. The predominant insect pests were various species of Diabrotica (Coleoptera, Chrysomelidae) which caused considerable reduction of the leaf area. The average number of damaged leaves was significantly reduced when potato was row-intercropped with rice and corn compared with damage on sole potato plot. The other associated crops, e.g., peanut, soybean and sweet potato were also heavily attacked by these pests, which may explain why the intercropped potatoes subsequently incurred severe pest damages. From the standpoint of overall vigor the potato-rice and potato-corn plots, stood out which may have helped in making them less vulnerable to pest attacks.

La Molina. A very interesting result was observed in that where wheat was used as intercrop, huge swarms of Dygliphus spp. (Hymenoptera, Eulophidae) which are parasites of the major insect pest, leafminer fly, Liriomyza huidobrensis (Diptera, Agromyzidae), were found. Consequently, the percentage parasitism on this pest in the potato-wheat plot was the highest followed by potato -sweet potato and potato-tomato. In the same experiment, it was observed that tuberworm damage was remarkably less in the potato-tomato intercrop compared with the others.

Discussion

From the foregoing results it is quite evident that various crop associations have differential effects on the development and spread of pests and diseases.
From the results in San Ramon it is clear that potato-tomato association is not advisable since both crops are hosts to late blight. Unless they have resistance to the disease, mix cropping them is unadvisable.

It is contended that the highly favorable microclimate in the potato-sweet potato intercrop greatly contributed to severe blight. In many instances sweet potato plants crept over the potatoes, sometimes covering their foliage. Since air movement was restricted relative humidity within the plot was high. Additionally, films of free water were retained longer on the leaf surfaces. All these greatly favored growth of the fungus hence the resultant severe damage by the disease. Conversely, the least affected potato-sorgum plot was open, disfavoring a microclimate conducive to the development and spread of late blight.

In Yurimaguas intercropping with rice gave the least damage by Diabrotica spp. to the associated potato plants. Apart from the fact that rice and corn are not primary hosts of the pest species, the intercropped potatoes were vigorous and well-developed; which condition may have helped in reducing their vulnerability to pests. It will be noted that peanut, sweet potato and soybean are all hosts of Diabrotica spp. As such the intercropped potato plants became more easily vulnerable to the damages they inflicted.

In La Molina it was observed that Dygliphus spp. parasites were particularly abundant when the associated wheat plants were in flower. It is speculated that some stimuli, possibly scent, yellow color of the wheat flower, and/or others, may have contributed to this occurrence. No attempt was made to determine the reasons for the differential attraction of the various associated crops to the mentioned parasites.

In summary, it is clear that mix cropping (polyculture) aids in reducing or stabilizing pest and pathogen populations and subsequently lessens the damages they inflict. With the threat of potentially destructive insect pests and pathogens in the tropics, where potato growing is being introduced, or where potato growing is being expanded, it is felt that much would

be gained with a through appreciation of polyculture, a very conspicuous feature of many farming systems in the region. The pest stabilizing properties of polyculture should be capitalized upon, since it has built-in pest management components which are attractive to the small farmer.

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ACCEPTANCE OF DIFFUSED LIGHT POTATO SEED STORAGE TECHNOLOGY IN DEVELOPING COUNTRIES

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An applied agricultural scientist's job is rarely finished once a promising technology for solving farm-level problems has been identified and tested on the experiment station. Indeed, a major challenge in agricultural development today -- and perhaps even more so by the year 2000 -- is how can scientific results be applied so that they answer effectively and efficiently problems in farmer's fields and stores. In short, how can we close the gap between scientific research and acceptance of results by people?

At least three general approaches have evolved to address the task of formal "technology transfer", the term used to designate the movement of scientific research to farmers.

Vertical linear approach

This traditional and widespread model involves a one-way transfer method that can be diagramed simply:

RESEARCH:
Laboratory or Experiment Station
↓
EXTENSION:
On-Farm Trials, demonstration and teaching
↓
FARMERS

This approach has been widely criticized since it reflects a top-down bias wherein scientists decide the relevant problems, seek solutions on their own accord, and convey results to the extension service which in turn passes technology down to farmers (Whyte, 1981). Research, extension, and farmers are conceived as separate, hierarchial entities with each having distinct roles. Farmers in particular are passive recipients of technology and knowledge.

Horizontal feedback approach

The need to give extension services and farmers a voice in the research process began to gain momentum in the 1960s and 70s. Unlike the traditional vertical agricultural research and development approach, emphasis shifted toward the belief that information should flow both directions. Feedback from farmers to extension to research was seen as crucial to success.

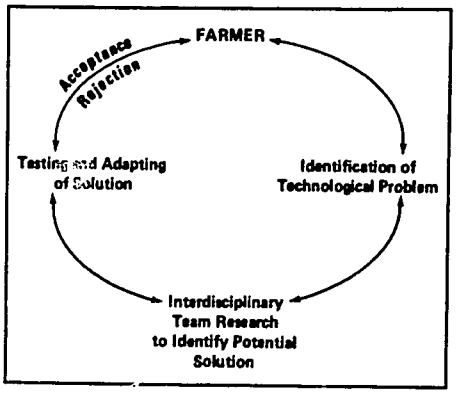
RESEARCH: ⇄ EXTENSION ⇄ FARMERS

Despite improvement in communication flow, this model is still linear and fragmented with farmers remaining recipients, not creative participants, in the research. The identification and design of technology in this strategy begin with scientists or policy-makers and end with farmers. The strength of information flow between entities depends on the viability of linkages which, due to social and economic reasons, are frequently weak in developing countries.

Farmer-back-to-farmer approach

A third alternative has recently been utilized by the CIP post-harvest interdisciplinary team in the identification, generation, and development of simple diffused light seed stores for developing countries. This model, developed through experience with small farmers, rests on the premise that research is a continuous process involving simultaneous input of farmers, scientists, and extensionists. Each should be fully participating members in the research and development of a technology. Applied agricultural research must begin on the farm through careful problem identification and end on the farm by farmer evaluation.

This circular, farmer-oriented model can be simply diagrammed:



Instead of a linear and fragmented approach, research and development activities go hand-and-hand with farmers continuously involved in the actual identification, design, testing and -- obviously -- evaluation and extension of the technology. Research must come full circle back to the farm where success of efforts is judged by farmer acceptance.

Diffused light storage: testing and adaptation

The crucial first step in the farmer-back-to-farmer model is careful identification of farmers' problems. Thus, the CIP post-harvest team of social and biological scientists began by studying storage practices in the Peruvian highlands. Three basic questions were asked:

1. How do farmers presently store?
2. Why do they store this way?
3. What are technological problems perceived by farmers and scientists in the present system?

Through selective elimination, the team identified seed potato storage as a major concern to potato growers. In particular, farmers recognized problems of excessive sprout elongation during storage and labor costs associated with desprouting before planting, especially with improved varieties introduced into the valley over the past two decades.

The team conducted parallel on-farm and experiment station trials wherein the known scientific principle of utilizing diffused light to reduce sprout elongation and improve seed quality was tested as a potential solution. On-farm research additionally addressed acceptable adaptation of the principle to traditional farm compounds and stores. It was quickly learned that agricultural development is not merely a technical matter but a socioeconomic one as well. Adaptation of the technology involved considerations of availability and cost of materials, architecture, security, and cultural perceptions. This testing and modification led to confidence in the technology as a low-cost solution to seed storage problems in developing countries.

Extrapolation from the Andes

A crucial question in international agricultural research is whether a technology can be extrapolated from the test region to other world areas. To answer this, the post-harvest thrust developed cooperative research and training programs through CIP's regional network with national potato scientists from 21 countries. A follow-up study of the storage activities of national scientists and farmer response illustrated the importance to national scientists of tailoring research and use of the technology to the conditions faced by farmers in their countries. Thus, while general principles can be extrapolated, "packaged technology" can rarely be transferred.

Much emphasis has been placed on the resistance to change by small farmers as a reason for the slow rates of agricultural

technology adoption in developing countries (Millikan and Hapgood, 1967). Our study of various countries where the diffused light storage has been introduced is that farmer traditionalism may be less a barrier to acceptance than the research and extension systems which are set up to "transfer" technology to farmers.

Approximately 800 adopters of the technology have been reported; most of these occuring in a few countries. These countries (e.g., Philippines, Peru, Colombia) share the following characteristics compared to cases where the technology has not moved at all:

Strong commitment on the part of national scientists to improving seed storage as an integral part of an overall seed program;

National scientists did not unquestionably accept the technology from CIP but tested it under their conditions;

Research, extension, and farmers cooperated closely in the research testing stage;

Technology was adapted with farmer advice so that it was economically and culturally acceptable in local contexts;

Local promoters were knowledgeable of village conditions, had excellent rapport with farmers and used effective demonstrations that showed a wide range of possible ways of adapting technology;

Follow-up by scientists and extensionists especially in the early adoption stage to refine and improve the technology.

If these conditions were not present in a country, the technology never reached farmers in a form they understood or could use. Analysis of positive farmer response to the technology the Philippines, Colombia, and Peru further points to the eagerness of small farmers for new technology if it solves their problems, is within their means, and adaptable to their situation. In fact, in all three countries many farmers living near demonstration or experimental stores started adopting the technology on a partial trial basis before seeing if the technology increased production in the field. Interestingly, adopting farmers rarely copied exactly the demonstrations stores. They took great pride in altering the technology to fit their own circumstance. In fact, CIP and national scientists learned from farmers the potential diversity in forms of adapting and improving the technology to fit their conditions. In the Philippines, small farmers simply replaced corrugated galvanized sheets on traditional multipurpose stores with one or two corrugated plastic sheets costing only US$ 2.00 each. In another Philippines case, however, 42 small farmers decided to jointly construct a 100 ton stores instead of building individual ones. In Peru and Colombia adoption ranged from simply spreading tubers under a veranda where indirect light enters to construction of stores with designs similar to demonstration models. However, even when new structures were built farmers improved the design in terms of loading, ventilation, and many other aspects. The technology has moved most rapidly in small communities or among cooperatives and farmer associations. Farmers learning from farmers seemed to be the most common means of spreading the technology.

In conclusion, the storage case as studied to date points to a common sense but often forgotten point. Effective and useable technology is generated by adaptive research systems grounded in the reality faced by farmers. The best partners that scientists could have in the research system are farmers themselves. By beginning and ending with farmers, the chance of acceptance is greatly enhanced.

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FUNGAL DISEASES OF POTATOES IN BRAZIL - PRESENT AND FUTURE TRENDS IN RESEARCH

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Presently, there are four Brazilian states - Espíritu Santo, Minas Gerais, Goiás, and Sao Paulo - participating in the Agriculture Research Cooperative System, as it relates to fungous diseases of potatoes. In 1980, however, three other states - Paraíba, Pernambuco, and Rio de Janeiro - in addition to the four above mentioned, presented research projects in this area.

The number of research projects in relation to the diseases and areas of study for 1980, 81, and 82 are shown in Table 1. Some of the research projects may involve more than one disease and/or area of study. Table 2 shows the number of research projects dealing with fungous diseases of potatoes, total number of plant pathology - potato projects, total number of potato projects (all areas of research), and total number of research projects for all crops contemplated in the National Research Program for Vegetable Crops (PNPO) in 1981 and 1982. The position of the research projects on fungous diseases of potatoes in relation to the total number of research projects in the PNPO, as well as total budget, is reported in Table 3.

The most common and important fungous diseases of potatoes are considered to be:

1- Late blight, caused by Phytophthora infestans. This disease is more common in the southern part of Brazil, although it also occurs in dryer areas of the central part of the country. Most of the efforts to control this disease involve fungicides. The cultivar planted to the most extent ('Bintje') is highly susceptible to this disease, which makes frequent fungicide sprays necessary (as many as 30 applications per cycle). The breeding programs also take into consideration resistance to this as well as other diseases, but rely solely on natural infection for disease resistance evaluation.

On chemical control, new systemic fungicides are being tested, as well as dosage

Table 1. Research projects per pathogen and area of study.

Study Area	1980 No.	1981 No.	1982 No.
Alternaria solani			
Fungicide	4	2	2
Resistance	1	1	1
Survey	3	-	1
Fusarium spp.			
Fungicide	-	1	1
Survey	-	-	1
Phytophthora infestans			
Fungicide	5	3	3
Resistance	1	1	1
Survey	3	-	1
Rhizoctonia solani			
Fungicide	-	1	1
Survey	-	-	1

Table 2. Number of research projects in the National Research Program for Vegetable Crops (PNPO) compared with potato projects.

Year	PNPO total	Potato: Total	Potato: Plant pathology	Potato: Fungous diseases
1981	314	44	12	5
1982	356	56	11	5

Table 3. Position of the research projects on fungous diseases in relation to the total number and total budget of the National Research Program for Vegetable Crops.

Year	% Total No.	% Budget
1980	2.3	-
1981	1.6	0.8
1982	1.4	0.8

and time of application. Special attention is being paid to the problem of fungus resistance to the fungicides.

2- Early blight, caused by Alternaria solani. The Brazilian breeding programs have been successful in releasing cultivars with high levels of resistance. In a test we conducted comparing the degree of resistance (measured by lesion size and number) of seven cultivars, 'Aracy' was found to be most resistant, and 'Edzina' the most susceptible. New fungicides are being evaluated, and frequency of application and dosage are of extreme importance.

3- Silver scurf, caused by Helminthosporium solani. This disease, although infrequently observed during harvest, is becoming increasingly common during seed-potato storage. Several shipments of seed-potato imported from different countries have shown high levels of infection. In order to evaluate the importance of silver scurf on yield, we have tested three cultivars with different infection levels in the seed potato. We have found no statistically significant differences

on yield or disease level in the first generation.

4- Brown - eye, caused by Cylindrocladium clavatum. This disease is discussed in detail, in another paper (Lopes et al.) in these "Proceedings".

5- Black scurf, caused by Rhizoctonia solani. Black scurf is widespread in Brazil. In the wet season (September-April), it is often associated with Erwinia rots of the stem. The disease also presents a special problem on fields for certification, since aerial symptoms, under certain conditions, are similar to those caused by potato leafroll virus. It can be considered one of the most important soil-borne diseases in the Cerrado region; this is aggravated by rotation with other susceptible crops. In our experiment station, it was shown to be the most important disease on seedlings from true seed transplanted to field.

6- Dry rot, caused by Fusarium spp. This is considered to be the most important disease of seed-potato in Brazil. However, there has been no comprehensive survey determining the species involved or losses. Chemical control has been used to a very small extent. Potato production is also affected by dry rot especially because of the traditional washing techniques of tubers for consumption. The lack of mechanical harvesters also contributes to increase the dry rot problem because of excessive handling of tubers.

Future needs

We believe that the main areas that should be studied are:

determination of fungicide efficiency, dosage, and frequency of application.

control of storage decays, specially Fusarium dry rot.

plant disease surveys in the main potato-producing areas.

careful evaluation of new systemic fungicides, especially against late blight.

evaluation of Brazilian and foreign cultivars and breeding material in relation to disease resistance.

if true seed is to expand in acreage, Rhizoctonia solani control has to be studied in detail.

EXTREME RESISTANCE TO POTATO LEAFROLL VIRUS (PLRV) IN SEEDLINGS OF SOLANUM ETUBEROSUM X S. PINNATISECTUM (EP) WITH 4 X CHROMOSOMES

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Summary

EP hybrid (4X) seedlings were inoculated with PLRV viruliferous aphids (Myzus persicae Sulzer) and as scions grafted onto PLRV infected Datura stramonium stocks to determine seedlings response to PLRV. PLRV resistant seedlings were further tested by ELISA serology and back grafting on healthy Datura plants. Susceptible, resistant (resistant to aphid inoculation, susceptible to graft inoculation), and extremely resistant (uninfected by either aphid or graft inoculations) seedlings were identified. Crosses within the above EP (4X) are in progress to study inheritance of PLRV resistance.

Introduction

Solanum etuberosum Lindl., a non-tuberous species, was reported to have a high level of PLRV resistance (Jones, 1977). Hermsen and Taylor (1979) successfully hybridized S. etuberosum with tuber bearing S. pinnatisectum Dun. and later Hermsen et al. (1981) doubled the chromosome number of sterile F_1 hybrids of S. etuberosum x S. pinnasectum and produced fertile allotetraploid (code 4X-EP). True potato seed of this EP material was made available to CIP by Dr. Hermsen of Institute of Plant Breeding (IVP), Agricultural University, Wageningen, The Netherlands, to evaluate its resistance to PLRV.

Materials and methods

Each of 4X-EP seedlings were inoculated with 30 PLRV viruliferous aphids. Aphids were killed by an insecticide after one week of exposure. Seedlings were observed for visual PLRV symptoms and tested by ELISA and scion grafting onto healthy Datura stramonioum for the presence of PLRV. EP seedlings with resistance to PLRV were scion grafted onto PLRV infected Datura and 2 months later these scions were back tested by grafting onto healthy Datura to determine the level of PLRV resistance in each seedling.

Results and discussion

None of the seedlings showed any visual PLRV symptoms either by aphid inoculations or scion grafting onto PLRV infected Datura. ELISA values were also extremely low almost giving negative results. However, from some seedlings PLRV was recovered by scion grafting onto healthy Datura either after aphid or only after Datura inoculations. Few seedlings did not become infected either by aphid or graft inoculations. On the basis of this response, susceptible, resistant , and extremely resistant seedlings were identified (Table 1). This is the first report of discovery of such extreme PLRV resistant in 4X-EP hybrid seedlings. None of the cultivated materials have ever shown real PLRV resistance so far.

Table 1. PLRV resistance in 4X-EP hybrid seedlings.

Parents	Extremely resistant 1/	Resistant 2/	Susceptible 3/
EP27 X EP11	1	1	1
EP50 X EP11	-	-	2
EP28 X EP29	1	2	-
EP28 (X)	-	1	2
EP36 (X)	3	1	1
EP50 Sp.	1	2	2
EP35 X EP31	-	1	3
EP29 (X)	2	1	2
EP36 X EP27	2	1	2
EP27 (X)	1	-	3
EP11 (X)	1	-	4
EP31 (X)	2	-	3

(X) = selfing; Sp. = spontaneous fruit set.

1/ Number of plants resisting infection by aphids and by grafting.

2/ Number of plants resisting aphid infection but susceptible to grafting.

3/ Susceptible to both aphid and graft infection.

To eventually incorporate this valuable PLRV resistance into the cultivated material, crosses within above EP are in progress at CIP study the inheritance of PLRV resistance. Furthermore, Hermsen et al. (1981) reported successful crosses of 4X-EP hybrids as females with S. stoloniferum and S. polytrichon and as males with S. verrucosum and feel this as the last step towards crossability with S. tuberosum which may make possible gene transfer from S. etuberosum to develop potato cultivars with extreme PLRV resistance by the year 2000 or earlier.

Acknowledgements

Thanks are due to Dr. Charles Brown of CIP for providing me 4X-EP seedlings used in this study.

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EFFECT OF GLANDULAR TRICHOMES ON THE SPREAD OF POTATO VIRUS Y (PVY) AND POTATO LEAFROLL VIRUS (PLRV) IN THE FIELD

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Summary

Glandular hairs in Solanum berthaultii Hawkes defend plants against several insect and mite pests by physically trapping and immobilizing foliage-feeding pests.

Spread of potato virus Y (PVY) and potato leafroll virus (PLRV) by Myzus persicae (Sulzer) in field trials was evaluated using two accessions of S. berthaultii, PI 310971 with type A hairs and PI 265858 with type A and B hairs. Both accessions were susceptible to PVY and PLRV. At harvest both accessions were equally infected with PVY, indicating that type A and B hairs had no effect on PVY spread. However, the spread of PLRV was reduced significantly by type B hairs (PLRV spread was 84% in PI 310971 and only 22% in PI 265858). Efforts are being made, at CIP, to breed clones with type B hairs to reduce PLRV spread under field conditions.

Introduction

The wild Bolivian potato species Solanum berthaultii Hawkes, is defended against infestation by small, soft-bodied arthropod pests by its dense vestiture of glandular pubescence (Gibson and Turner, 1977). The secretions of these hairs physically trap and immobilize several insect pests including aphid Myzus persicae Sulzer.

Direct feeding damage by aphids to potato crops is only occasionally important, the costs incurred as a result of aphid-borne viruses are much greater (Strickland, 1965). M. persicae is a main vector of most common and destructive viruses, potato leafroll virus (PLRV) and potato virus Y (PVY) (Broadbent, 1953). Yield losses by these viruses can be as high as 90% depending on cultivar, infestation and environmental conditions. No studies have been reported on the effect of glandular trichomes on virus spread by M. persicae. We report here for the first time effects of these trichomes on PLRV and PVY spread in the field.

Materials and methods

True seed of 2 accessions of S. berthaultii PI 265858 and PI 310971 were obtained from the Potato Introduction Station, Sturgeon Bay, Wisc. and were sown in peat-vermiculite soil mix. PI 265858 has 2 types of glandular hairs, a short type with a tetralobulate gland at the tip (Type A) and a longer multicellular hair with an ovoid gland at its apex (Type B). PI 310971 lacks the prescence of Type B hairs and, therefore, is more susceptible to aphid infestation (Gibson, 1979). In the greenhouse M. persicae reared on PLRV infected Peruvian cultivar Ticahuasi were transferred to seedlings, 5 aphids/plant, later the population development was assessed after 10 days. Plant reaction to PLRV was later determined on these infested seedlings.

In the field plants of both accessions were interplanted with PLRV infected plants of Ticahuasi as a source of inoculum in the field for the natural spread of PLRV. A total of 8 rows for each accession, with distance between rows of 0.90 m with 0.3 m interval within the row were planted. No insecticides were used, populations of apterous M. persicae were determined by visual examination of adaxial surfaces of fully-expanded leaves from the lower 1/3 of randomly-selected plants. Virus evaluation was conducted by selecting 3 tubers at random for each of the harvested plant, tuber replanting in the greenhouse for secondary PLRV symptoms and testing by ELISA serology. Back inoculations to Physalis floridana and grafting to Datura stramonium were also performed as evaluation tools.

Results and discussion

Results are summarized in Tables 1 and 2. The mean aphid population on PI 310971 was 31/plant 10 days after confinement. In comparison PI 265853 had 8 aphids/plant, with majority being stuck to glandular hairs (Table 1). These results indicate that Type B hairs in combination with Type A hairs are essential in suppressing aphid population. Under greenhouse conditions both accessions were equally susceptible as 4 of 5 plants were infected in each case. When aphids were given no choice, they were able to transmit the virus. However, under field conditions very interesting results were observed. Both accessions were 100% PVY infected indicating natural presence and spread of PVY and no control by glandular hairs of either type. However, in case of PLRV spread, very useful results were obtained. PI 265858 showed 22% PLRV infection and PI 310971 up to 84% indicating that the presence of type B hairs significantly reduced the spread of PLRV infection under field conditions (Table 2).

Table 1. Effect of glandular hairs in Solanum berthaultii on multiplication of Myzus persicae.

Accession	Hair type	Aphids/plant after 10 days[1/]					
		Plant number					Average
		1	2	3	4	5	
PI 265858	A & B	20	8	12	2	5	8
PI 310971	A	55	32	28	15	25	31

[1/] Initially 5 aphids were placed on each plant.

As in the greenhouse study the populations of M. persicae were significantly lower on PI 265858 due to rapid entrapment and immobilization by glandular trichomes. These could have caused decreased plant to plant movement of viruliferous apterae or alatae and as a result this may have led to reduced spread of PLRV. These results suggest that increased emphasis should be placed in the future to breed potato cultivars with glandular hairs derived from S. berthaultii as a means of restricting the spread of PLRV in potato crops.

Table 2. Effect of glandular hairs in S. berthaultii on PLRV and PVY infection under field conditions.

Accession	Hair type	% Infection	
		PLRV	PVY
PI 265858	A + B	22 a[1/]	100 a
PI 310971	A	84 b	100 a

[1/] Means followed by different letters are significantly different at P >0.01 level.

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URGE FOR A BETTER KNOWLEDGE OF APHIDS AS A MEANS TO IMPROVE LOCALLY ADAPTED CHOICES OF STRATEGIES FOR AN INTEGRATED CONTROL

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Until recently, both selection and multiplication of potato seed was done in temperate countries situated mainly in the northern hemisphere. For some fifteen years, many countries located in climates of the Mediterranean and/or tropical types have been trying to free themselves more and more from financial constraints due to the necessary importing of foreign seed potatoes. They wish to improve their seed production to supply their own needs. To a large extent, they must face a great many problems of zoological and phytopathological origin, among which the rapid dissemination of aphid borne virus diseases into and within crops is one of the most frequent and worrying.

Contrary to what usually occurs in regions and countries with a long tradition of seed potato production, any knowledge about vector species, virus strains and environmental conditions is very scarce or lacking: Hence, there is a great temptation to take the more hasty and immediate measures to try and overcome any peculiar problem which may arise. Often, the crop protection technology and technical rules from developed countries are used without checking whether they fit or not the special situations.

The use of pesticides is one of those choices although it often represents a great export of currency. Moreover, at a short term level, consequences may be very important. Many people unfortunately still believe that just killing the aphids with insecticides will result in preventing virus disease transmission and dissemination. We know that this is quite wrong as regards non-persistent virus transmission and partly true in some cases for persistent viruses. The screening for efficiency of different aphicides or mineral oils to prevent virus dissemination, if ever effectively done, applies mainly to temperate situations, so it is with formulations, time of application, etc. For instance, application of granular systemic persistent aphicides in the furrow at planting may result in a good effect if the aphid contamination, flight, and building up of apterous populations of aphids occur as soon as the plants emerge. This cannot yet be of any use if aphids arrive too late or if irrigation in the furrow has been chosen, with the active ingredient flowing away.

The side effects of pesticide application have not been sufficiently well defined, and non target insects (pollinating ones, aphid enemies...) are often destroyed as a consequence of insecticide use against aphids or other damaging insects. Carbaryl against the Colorado potato beetle or noctuid moth larvae and probably in the near future, pyrethroids with a broad spectrum efficiency against many insects.

At a long term scale, two sources of aphid population outbreaks may arise:

(1) Aphids may become insecticide resistant, owing to chromosomal mutation and/or insecticide pressure as is well known to occur very commonly within M. persicae Sulz. in cross resistance against organophosphorous, carbamates and pyrethroids. This is particularly dangerous when continuous parthenogenesis has become the rule as it is for aphids in mild and tropical countries.

(2) Killing aphid enemies may result in disrupting the fragile biological equilibrium with unforeseeable consequences.

An alternative solution lies in the search for virus resistant cultivars which indeed proves very seductive provided one keeps in mind that viruses are mainly aphid borne and transmitted. We know there is no necessary relationship between virus resistance and aphid resistance and a so-called virus resistant cultivar may be very susceptible to aphid attack and/or "produce" a considerable number of aphids which must be considered as potentially "polluting" vectors for other cultivars in other crops. The problem of virus strains and aphid species and strains must be carefully studied and taken into account as we do not usually know precisely whether the same ones will occur in the various countries involved with potato seed production as compared to what is observed under temperate conditions. The recent discovery of a potato leafroll inducing agent being a Beet Western Yellows Virus (BWYV) isolate is one among other examples showing the limits of our knowledge even under apparently so well known conditions such as those occurring in California and Oregon (USA). The equivocal belief that M. persicae being the more efficient virus vector under laboratory conditions must not be considered de facto the more efficient also, under natural conditions. Some dissemination can occur both in its almost complete absence and the abundance of other so called poor vectors species (PLRV and PVY and respectively with Aulacorthum solani, Rhopalosiphum padi and other species). This emphasizes still more the necessity of a better knowledge of the different epidemiological factors whenever a choice is going to be made.

Using the integrated control concept to avoid long term damage to the environment, it seems very desirable to begin with exploiting all the "natural" possibilities offered locally in so far as a complement to such other alternatives as chemical control or search for resistance. As for aphids, for instance, one of the first concerns should be the questions "where, when and how" do we get aphids and what about aphid enemies? The second one would be "where, when and how" can we escape aphid infestation and population building up. Seasonal activity of aphids under the tropics shows that the answers are not beyond the scope. This would at least permit one to choose more appropriate planting dates possibly enabling the plants to get more resistant physiologically before aphid arrival and would render useless many of the systematic treatments with the irretrievable consequences they imply.

EFFECT OF QUANTITY OF LIME AND ITS DEPTH OF INCORPORATION ON GROWTH AND YIELD OF POTATO IN AN ACID SOIL

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Introduction

In tropical climates, to where the expansion of potato production is being directed, many soils are acid with a high aluminium saturation of the cation exchange capacity (CEC). Therefore, root systems of potato and other acid sensitive plants are injured by the soluble aluminium, hence mineral nutrient and water uptake are restricted and yield potential reduced.

Lime application is necessary to neutralize exchangeable aluminium and to permit a more extensive root system, particularly important for nonirrigated crops in a tropical dry season. The beneficial effect of deep liming under drought stress conditions has been demonstrated for maize (Gonzalez, et al., 1979) as has been that of deep cultivation for a number of temperate crops (Rowse and Stone, 1980). In the hot tropics potato performs best in the dry season (Midmore, unpublished), due to the cooler nights, high radiation receipts, and less disease. To further improve yield during that season, stimulation of a deeper root system by deep lime incorporation was attempted. The residual effect of the treatments on successive crops is being monitored.

Materials and method

The experiment was carried out at Yurimaguas, Peru (5°45'S, 76°05'E, 179m). Annual rainfall averages 2150 mm, maximum temperature 31.2° and minimum consistently around 20°C. The soil is a Typic Paledult with pH 4.5 and 66% aluminium saturation of CEC.

A split-split plot design with three blocks was used, in which the main plots were three depths of lime incorporation: superficial, 0-5 cm; medium, 0-15 cm; deep, 0-30 cm. Medium and deep incorporation was made with a rotovator whereas superficial incorporation was made by hand. The subplots were three rates of lime: 0X, 1X and 2Xmeq Ca/100ml soil, based on the soil volumes of the respective main plots, where X=meq Al/100 ml soil. The sub-subplots were two potato clones LT-2 and Mariva, presprouted and planted on 26 May 1981 each in plots of five 5m rows spaced at 0.3m within and 0.7m between rows. Fertilizer was applied at the rate of 160-160-200-50 kg/ha of N, P, K and Mg. Serial samples for growth analysis were taken throughout the season until maturity was reached 71 and 96 days after planting by LT-2 and Mariva, respectively.

Results and discussion

A similar response of both clones to the different treatments was obtained, therefore, only mean values are presented. Yield was improved by both lime application and deeper incorporation (Figure 1). The 1X lime rate increased yield over the control by 73, 21 and 38% respectively for the shallow, medium, and deep incorporation depths.

The 2X rate appeared super optimal, perhaps due to an overliming effect causing

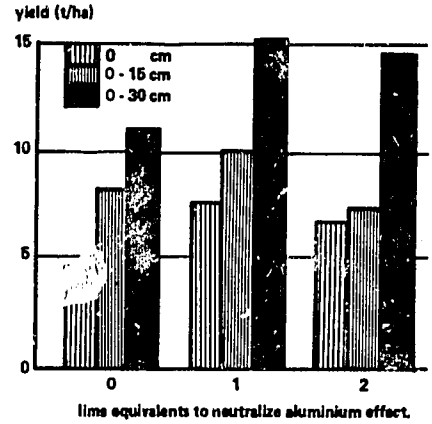

Figure 1. Potato yield (mean of two clones) after incorporation of various amounts of lime and rotovation at different soil depths. (Yurimaguas 1981).

deficiency of phosphorus or micronutrients (Kamprath, 1971). Increasing depths of incorporation resulted in yield increases even when no lime was applied. The latter suggests that aluminium toxicity was not severe and that a loosening of the deeper soil permitted better penetration of roots, as suggested by Rowse and Stone (1980). Deeper rotovation increased plant height, number of internodes, branches, and leaves (Figure 2), and the size of the root system. The 2X rate of lime had no beneficial effect on those measured characters, probably due to the earlier mentioned overliming effect.

Although emergence of the crop was unaffected by the treatments, the combination of more internodes, branches, and therefore, leaves in the medium and deep incorporation treatments tended to hasten the achievement of complete ground cover. This in turn would concommitantly improve interception of solar radiation and therefore soil cooling through self-shading, with a resulting yield improvement.

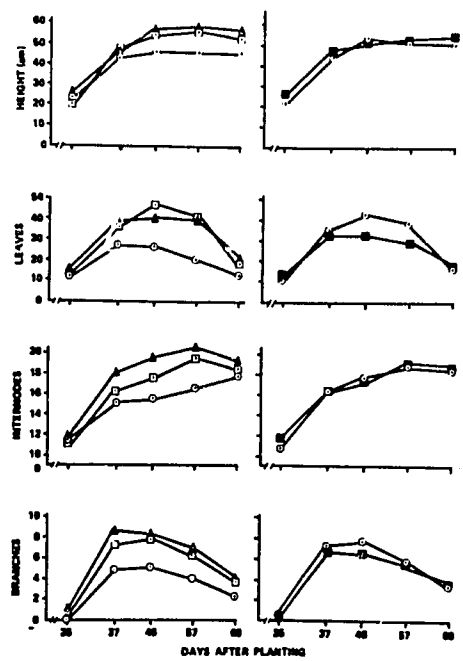

Figure 2. Effects of three depths of soil movement (⊙, 0 - 5 cm; △, 0 - 15 cm; ⊡, 0 - 30 cm) and two lime rates (⊙, - 0X; ■, - 2X; see text) on growth attributes of LT2.

Less water logging was noted in the medium and deep incorporation plots due to better infiltration. This may also have improved yield since problems related to high ethylene concentrations and low oxygen levels could be alleviated (Campbell and Moreau, 1979; Sojka and Stolzy, 1981).

Further studies on successive crops are in progress.

Acknowledgements

We thank Ing. L. Ramirez for computing assistance.

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MAJOR AND MINOR GENES IN BREEDING VIRUS RESISTANT VARIETIES

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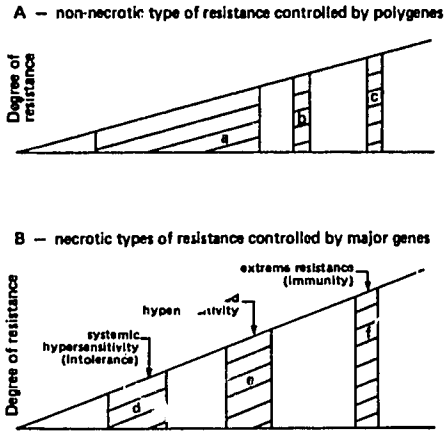
Genetic information initiates interdependent physiological reactions which together determine phenotype. Nevertheless, we can distinguish between genes of low and high expressivity. The former called minor genes or polygenes, cause a visible or perceptible effect only as a group of genes, situated partly in different chromosomes. The gene action can be partitioned into additive and non-additive components. Certain type of virus resistance are controlled by such minor genes. Minor genes are responsible for differences in what we call quantitative or infection resistance to PLRV, PVA, PVX or PVY and others. This type of resistance is non-necrotic, an outstanding example being infection resistance to PLRV in S. etuberosum (Figure 1-A).

But in some cases one gene among the group has a stronger influence and can be detected segregating in a Mendelian fashion. Such major genes have been found in wild species as well as in cultivars and breeding clones against all important viruses. Breeding is easier as high percentages of equally resistant progenies result from crosses with susceptible parents. While minor genes control resistance leading to



A. Non-necrotic types of resistance in which every individual can be infected in the field when infection is strong; controlled by polygenes influencing quantitative or infection resistance.
   a. occurring with PVA, PVM, PVS, PVX, PVY, PLRV, in certain cultivars.
   b. occurring in S. gourlayi to PVM.
   c. occurring in S. tuberosum to PLRV.

B. Necrotic types of resistance controlled by major genes influencing hypersensitivity, or extreme resistance (immunity).
   d. systemic hypersensitivity (intolerance) with field plants dwarfed or dying off; occurring with PVM gene Nm in S. megistacrolobum; PLRV major gene in some cultivars and wild species; PVY Ny gene in S. demissum, S. microdontum, and S. phureja.
   e. localized hypersensitivity with virtually no virus multiplication in field plants; occurring as Na gene to PVA in many cultivars; as Ns gene to PVS in S. andigena cultivars; and as Nx and/or Nb genes to PVX in many cultivars.
   f. extreme resistance or immunity with virtually no virus multiplication in field plants: occurring as Rx_{acl} in cultivars from S. acaule; Rx_{adg} in cultivars from S. andigenum; Ry_{sto} in cultivars from S. stoloniferum or Ry_{adg} in cultivars from S. andigenum.

Figure 1. Types of resistance to viruses in the potato.

a lower infection rate, a major gene provides a stronger defense. With minor genes systemic symptoms appear and yield may be reduced. Major genes control, however, necrotic reactions. Two groups of major genes can be distinguished: N-genes and R-genes. N-genes cause a hypersensitive reaction and the R-genes a reaction called extreme resistance or immunity, which is an enhanced hypersensitivity (Figure 1-B.) The two types can be distinguished by a graft test. The hypersensitive reaction is characterized by a top necrosis, i.e. necrosis of the top of the scion and sometimes of the whole plant. Backtests to indicator plants are positive. Extreme resistance causes a cessation of growth of the main axis, some localized necrotic lesions on the leaves and sometimes necrosis on the margin of lower leaves.

Systemic and localized hypersensitivity are not always clearly separated (Figure 1), depending on the genetic background. Localization of lesions may not be strong enough in all environments. Breeding lines with the Ny-genes from S. demissum, S. microdontum and S. phureja exposed to infections in the field, occasionally show systemic necrosis. Extreme resistance always prevents systemic infection.

R- and N- genes are inherited tetrasomically in crosses of cultivated tetraploids. In a cross between simplex resistant (Rrrr, Nnnn) and susceptible clones, between 45.8 and 50.0% resistant progenies are expected depending on the gene map distance between the resistance locus and the centromere. When crossing duplex resistant (RRrr, NNnn) and a susceptible clone between 77.8 and 83.3% resistant progenies are expected. In practice, deficiencies of resistant progenies have been noted in certain crosses suggesting influence of the genetic background.

Many N- and R- genes are already incorporated into cultivars. The gene Ry_{sto}, derived from S. stoloniferum, is present in 13 European varieties. Another R-gene is found in S. tuberosum ssp. andigena (Ry_{adg}). But Ny-genes for hypersensitivity of S. microdontum, S. chacoense and S. phureja are not incorporated into varieties to date.

Extreme resistance to PVX coming from different sources is widely spread among varieties all over the world. It is well known that the major gene resistance (vertical resistance) breaks down rather regularly in rust and mildew pathosystems. Concerning the above mentioned R-genes, the situation is different. Only 50% of the investigated R- and N- genes (based mostly on Cockerham's studies) for localized hypersensitivity or extreme resistance to potato viruses are strain specific (Table 1). For example, plants with Rx_{adg} and Rx_{acl} are susceptible to some PVX strains from Bolivia and Peru as Dr. L. Salazar and thereafter Moreira, Jones and Fribourg found. But no breakdown of RY, Ra and Ns has been observed until now. This is not an exception. Major resistance genes in other virus pathosystems like TMV in tobacco are not strain-specific. The reason is perhaps that the RNA of viruses is composed of relatively few genes. Nondeleterious mutations in genes controlling virulence should occur, theoretically at far lower rates in viruses than in fungi. Of course, we cannot be sure that the resistance remains stable forever. Raoul Robinson proposed an interesting term for cases of stable vertical resistance, calling them "frozen" vertical resistance, which characterizes this situation very well.

Unfortunately, genes causing strong necrotic localized defense reactions to PLRV have not been detected among hundreds of wild species, primitive, or modern cultivars. But, a milder form of hypersensitivity exists, i.e. systemic hypersensitivity or intolerance. Some cultivars such as 'Apta' after infection with PLRV become necrotic, heavily stunted and produce tubers in which most eyes do not sprout. These tubers may give rise to small plants that perish. This is a kind of self-cleaning mechanism. Since intolerance to PLRV is reported to be controlled by a single major gene, this in combination with Ry and Rx would be an effective defense against the three most

Table 1. Strain-specific and non-strain-specific genes for localized hypersensitivity and extreme resistance in the potato.

Virus	Strain-specific genes	Non-strain-specific genes
PVM		Nm
PVS		Ns
PVX	Nx	
	Nb	Nx_{acl}^{n}
	Rx_{acl}	x^{n}
	R^{x}_{adg}	Nx_{chc}
PVA/PVY	NA	Ry_{sto}
	Nc	Ry_{sto}^{na}
	Ny_{dms}	Ry_{adg}
	Ryn	Ry_{hou}
	Ry_{sto}^{rna}	Ny_{chc}
	Ry_{sto}^{n2}	
	10 :	10

important virus diseases. Such a combination would also be a perfect solution of the virus problem in the Andes and in comparable regions where the aphid infestation is not too high. With such varieties there would be less or perhaps no necessity for a regular supply of healthy tuber seed, a necessity which causes economic hardship in most underdeveloped regions. Thus, PLRV intolerant varieties with the genes Ry and Rx offer a possibility to low income farmers to become independent from buying commercial certified seed.

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TRUE POTATO SEED DRYING AND STORAGE OVER RICE

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A method is described for drying potato seed before storage using toasted rice grains as desiccant.

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SILVER SCURF DEVELOPMENT ON TUBERS

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When VTSC stock schemes were first developed it was conceivable that all tuber-born diseases could be avoided. However, silver scurf, due to Helminthosporium solani, is one of the diseases that quickly recontaminated clean stock (Hide and Bell, 1980).

The development of the TBZ treatment of seed tubers provides the additional control that is needed to prevent tuber contamination in storage. Cayley et al. (1979) thought timing of treatment could be important in relation to crop senescence and harvesting.

Data are presented on the rapid development of silver scurf after crop maturity and the failure of TBZ treatment at harvest to prevent this.

Method

TBZ treatment of seed

The seed crop, cv. Kennebec, was 3 multiplication stage removed from VTSC stock and had grown for 86 days before the haulms were desiccated with paraquat to limit tuber size.

Tubers were harvested 77 days after haulm destruction, and TBZ was applied on the same day for the control of gangrene and silver scurf. Forty five g (active ingredient) were applied as a mist in 2 l of water as tubers were passed over a grading machine at 6.7 t/hour (Treatment A). Comparable tubers were passed over the same grader without the TBZ application (Treatment B). A third batch of tubers was passed over the grader at 1.5 t/hour, the normal grading speed, and these were also left untreated (Treatment C).

A sample was rated for per cent surface area affected by silver scurf; for the purposes of analysis and discussion tubers with more than 25% coverage had significant disease.

Tuber weight loss over the storage period of 180 days was measured for trays containing an average of 13.6 kg, arranged in a randomized block design (ambient temperatures).

Silver scurf incidence

Treated and untreated seed was planted in 4 row plots, 25 plants per row, in a randomized block with 4 replicates. One row from each was harvested 20 days prior to haulm destruction by rotary slashing 130 days after planting. The remaining rows were harvested 24, 48 and 76 days after haulm destruction; tubers from the last harvest were held in storage for a further 42 days and rated again.

Tubers were washed and rated, and analysis of variance perfomed on the percentage with more than 25% cover.

Results

TBZ reduced weight loss in storage from untreated controls with losses of 11.82 and 11.24% to 9.50% with thiabendazole treated at grader speed of 6.7 t/hr. Differences between untreated controls and fungicide treatment were significant at the 1 percent level.

No significant effect of treatment on incidence in progeny tubers was found. Data were combined to show incidence at the various harvest dates. Chi square tests using the numbers of tubers with less than, and more than, 25% surface area affected showed a highly significant increase between the second and third harvests (24-48 days after naulm destruction). There was no change in the rating of the 4th harvest after storage.

Table 1. Incidence of silver scurf on tubers.

Time of tuber observation	Silver scurf incidence (%) <5	5-10	10-25	25-50	>50
seed at planting	7.2	14.3	16.8	22.9	38.8
before haulm destruction	100	0	0	0	0
after haulm destruction					
24 days	31.0	18.5	21.3	14.8	14.5
48 days	2.8	10.8	16.6	23.4	46.4
76 days	2.9	12.1	21.1	30.6	33.3
76 days + 42 days storage	2.2	8.0	22.8	32.6	34.4

There was no significant difference between the incidence of silver scurf on seed tubers and on their progeny tubers at the 3rd harvest, respectively 77 and 76 days after haulm destruction.

Discussion

Variable control of silver scurf has been reported by a number of workers. A possible reason for this variability is disease development prior to harvest. There has been no recognition of this effect in disease control recommendations, the emphasis being on the prompt treatment after harvest for effective control of gangrene.

Bandy and Leach (1981) have shown that TBZ is active in inhibiting the growth of H. solani, and treatment did reduce tuber weight loss in storage by 18% in the study reported here. At a sale price of $310/t for seed this is a saving of $55.80/t and well above the cost of treatment.

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EARLY DYING SYNDROME OF KENNEBEC POTATO

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An early dying disease due to Verticillium albo-atrum and V. dahliae has been described by Isaac and Harrison (1968) and Verticillium wilt has been recognised from Australia, New Zealand, Canada, and U.S.A.

V. albo-atrum has been isolated from the stems of some (but not all) plants affected by early dying in Tasmanian Kennebec crops, and also from apparently healthy plants (Sampson, 1980). Early dying disease was reproduced under glasshouse conditions after inoculation with V. albo-atrum. Tuber- and soil-borne inoculum was demonstrated, and may explain the failure to control early dying by a combination of pathogen tested stock plants produced from stem cuttings, a 5 year rotation with pasture between potato crops, and the removal of affected plants from seed crops.

The effect of early dying on tuber production was measured, and the possible relationship of early dying to differing physiological ages of seed tubers is discussed.

Methods

Round seed tubers of less than 80 g were stored at ambient temperatures at Elliot Research Station, latitude 41°S and elevation 100 m, and planted in October (Southern hemisphere). They were spaced 300 mm in rows that received 1780 kg/ha of a 5:6:9 NPK fertilizer mixture applied along the open furrow at planting time, and the crop was irrigated to maintain continuous growth. A water stress accidentally occurred soon after flowering.

Fifty healthy plants and 50 plants showing premature senescence as chlorosis and necrosis of upper leaflets, usually preceded by flaccidity, were marked when the symptoms were first recognized in mid January. The bulk of the crop showed similar symptoms as it approached maturity in late February.

A main shoot showing symptoms was collected from equivalent plants, and tissue from the lower stem was cultured on potato dextrose agar to determine if V. albo-atrum was present. After haulm collapse at full maturity (April) the tubers form each marked plant were lifted and then graded into size categories, and the weight in each category determined. A comparison was made between affected and healthy plants for the percentage of tubers in each size category and for total yield. A single tuber was retained from each plant to determine whether V. albo-atrum was present at the stolon end.

Results

There was no difference between healthy and affected plants for mean tuber number per plant, but healthy plants outyielded affected plants by 26.5%. The affected plants had a greater production of small tubers (less than 80 g size), and lower production of large tubers (250-350g, 350-700 g) (Table 1). Total yield of healthy plants was 1305 g and that of wilted plants was 960.2. The chi square test was significant at the 0.05 level.

V. albo-atrum was obtained from 7 of 13 stems and 14 of 52 tubers from affected plants, and from 1 of 52 tubers from healthy plants.

Discussion

When culls are excluded from the summation of yield, affected plants produced 28.2% less by weight than healthy plants. The syndrome is therefore of economic importance. Although V. albo-atrum was obtained from affected plants more frequently than from healthy, its absence from nearly half of the affected plants leads to the conclusion that it was not the immediate cause of the syndrome. Incomplete infection of potato stems and tubers by V. albo-atrum has also been shown by Isaac and Harrison (1968).

Table 1. Characteristics of tubers of different sizes from healthy and wilted plants.

Character	Tuber size (g) <80	80-250 g	250-350	350-700
Yield				
Healthy				
kg	31.7	475.0	420.8	377.3
%	2.4	36.4	32.3	28.9
Wilted				
kg	47.0	579.4	208.4	125.4
%	4.9	60.3	21.7	13.1
Chi square[1/]	3.9	2.3	11.1**	15.5**
Percentage of plants producing tubers of sizes shown				
Healthy	38	98	74	58
Wilted	56	94	52	16
Tubers per plant (%)				
Healthy	0.52	2.96	1.40	0.86
Wilted	0.84	3.50	0.72	0.28

1/ Chi square significance between yields of healthy and wilted plants at *p = 0.05, and **p = 0.01 probability.

Differences between buds on the one seed tuber which led to plants with different vigour and growth characteristics have been recognized (Korovkin, 1979). Separate seed pieces cut from tubers with a range of physiological ages would be expected to develop into plants with a wide range of times of maturation. The early maturing plants would be seen as showing wilt/early dying/premature senescence.

Infection by V. albo-atrum may therefore be only one of several possible causes of the early dying syndrome.

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BEET WESTERN YELLOWS VIRUS EPIDEMIOLOGY AND LEAFROLL OF POTATO IN TASMANIA

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A recent report for Tasmania confirms that beet western yellow virus (BWYV) is commonly present in potatoes affected by leafroll (Duffus and Johnstone, 1981).

The available information on leafroll and BWYV in Tasmania is reviewed to consider by what mechanisms the certified seed scheme achieves control of leafroll.

Certification scheme

Four multiplications of the major cultivar, Kennebec, are undertaken at Tewkesbury Potato Station, located in an exposed area of native eucalypt forest at an altitude of 500 m above sea level. Isolation from other cropped areas is excellent. Control of self sown potato plants is achieved by a pasture phase in the rotation. Multiplication is based on a nucleus of selected plant units.

Two further multiplications are undertaken by potato growers at altitudes above 250 m; certification officers regularly inspect the crops and visually diseased plants are removed to conform to a high standard.

Inoculum potential

A low but variable incidence of secondary leafroll in seed crops has been observed over the period 1930-1970. The plant units at Tewkesbury were replaced in 1970 by the annual production of pathogen tested stem cuttings (VTSC) from stock plants maintained under glasshouse conditions. Granular insecticide was applied at planting of the first, second and third multiplications. The incidence of leafroll as assessed in 100 tuber samples subsequently dropped to a very low level (Table 1), and the use of insecticide was discontinued after 1978.

Leafroll is common in commercial potato crops in areas of arable farming, and may affect a significant proportion of plants if certified seed is not used to produce seed tubers. It has been concluded that spread of leafroll under such conditions is mainly from within the crop (Howell, 1975).

Table 1. Number of crops and percentage of plants showing secondary leafroll after 4, 5 and 6 years of seed multiplication in the years indicated.

Year	Year of multiplication					
	4th		5th		6th	
	No. Crops	LR %	No. Crops	LR %	No. Crops	LR %
1969-70	4	0.5	2	0	34	3
1970-71	1	0.3	21	0.5	23	1
1971-72	1	0	9	3	42	0
1972-73	1	0	7	0.3	34	5
1973-74	1	0	7	0.5	37	4
1980-81	1	0	80	0	90	0.1

Many species of weeds and crops plants are reported, or are likely to be, hosts of BWYV (Duffus, 1960, 1964). Capsella bursa-pastoris (Shepherds's purse) is commonly infected in areas of arable farming. This species overwinters and is a biennial. Other known weed hosts include Brassica spp., Malva sylvestris, Senecio vulgaris, Trifolium subterraneum, Coronopus didymus, Calendrinia caulescens, Lactuca serriola, and Sonchus oleracea.

Aphid vectors and their distribution

For leafroll spread in S.E. Scotland, Howell (1975) concluded Myzus persicae to be the most important vector; Macrosiphum euphorbiae activity had a comparable correlation and Aulacorthum solani and Aphis fabae may also have had an effect in some seasons. Brassica crops and glasshouses, and perhaps wild weed species, were viewed as potential overwintering sites.

Of these aphid species, M. persicae and M. euphorbiae are vectors of BWYV (Duffus, 1960). They have been recorded from relatively few weed hosts in Tasmania (Martyn and Miller, 1963). The ability of A. solani to transmit BWYV has been confirmed (Johnstone, personal, communication). All three species occur in Tasmania throughout the potato growing period (Tables 2, 3).

Aphid vector activity

Yellow trap data on the numbers of alates of the three aphid species at Tewkesbury during the months November to March are summarised for several seasons (Table 2). Low numbers of M. persicae and M. euphorbiae were typical, while A. solani reached high numbers, mainly in each late spring.

Similar data for Forthside Vegetable Research Station, altitude 70 m, in an area of arable cropping and commercial potato production are given (Table 3). Relatively high populations of the vector species were registered.

Table 2. Yellow tray aphid catches of 3 vector species in the years indicated at the Twekesbury Potato Station, during the potato growing period of November-March.

Year	Aphid Species 1/		
	Mp	As	Me
1963-64	17	67	34
1964-65	3	84	20
1965-66	51	227	31
1966-67	47*	1*	3*
1967-68	2	653	11
1968-69	2	69	7
1969-70	4	725	8
1970-71	8	154	20
1971-72	3	182	8
1972-73	5	1546	13
1973-74	4	200	7
1974-75	3	67	6
Mean	12	333	14
Mean (full year)	6	359	15

* incomplete
1/ Mp = Myzus persicae, As = Aulacorthum solani, and Me = Macrosiphum euphorbiae.

Table 3. Yellow tray aphid catches of 3 vector species at the Forthside Vegetable Research Station in the years indicated, during the potato growing period of November-March.

Year	Aphid Species 1/		
	Mp	As	Me
1966-67	939	323	236
1967-68	777	240	229
1968-69	21	150	6
1969-70	59	2114	14
1970-71	34	117	11
1971-72	3	753	9
1972-73	11	213	7
1973-74	2	62	4
1974-75	-	463	6
Mean	231	493	58
Mean (full year)	335	634	62

1/ Mp = Myzus persicae, As = Aulacorthum solani, Me = Macrosiphum euphorbiae.

Discussion

The low incidence of leafroll at Tewkesbury shows BWYV to be endemic there. The introduction of VTSC stock reduced leafroll incidence, indicating the virus reservoir of BWYV is potato and that weed species are not important as sources of the virus. The lower leafroll incidence was maintained despite suspension of insecticide use, which indicates aphid activity is not the limiting factor for leafroll spread. A very low inoculum potential could explain the situation seen at Tewkesbury. Low aphid activity could contribute to the low inoculum potential.

These limitations also apply to the later multiplications undertaken by seed growers, with the important difference that aphids do succeed in introducing BWYV from a source outside the crop. Aphid numbers are presumably comparable to those recorded for Tewkesbury. It is therefore inferred that a greater proportion are infective because BYDV sources occur more frequently within aphid flight range. These could be as infected potato plants, or crop or weed species, as far away as the commercial cropping areas (usually in excess of 5 km).

At Forthside and in commercial crops, the high numbers of aphids indicate their much greater activity and so the possibility of leafroll spread. Potato and weed hosts are commonly infected with BWYV in this area and there appears to be no limitation for spread of leafroll other than climatological and biological control factors on aphid reproduction.

It is concluded that the immediate reason for the low incidence of leafroll in seed potatoes is the low inoculum potential of BWYV in potato at Tewkesbury Potato Station. The recognition that BWYV is a major cause of leafroll and has a wide host range including weed and crop species does not alter the interpretation of the principles of seed certification.

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RESISTANCE IN POTATO TO POWDERY SCAB, DUE TO SPONGOSPORA SUBTERRANEA

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Summary

Powdery scab occurs under cool, temperate growing conditions, and is the greatest single cause of loss from disease in crops of cvs Kennebec, Sebago and Sequoia in Australia. Its control by cultural and chemical means is unreliable and inefficient. Useful resistance is demonstrated in Russet Burbank, and is required in new cultivars for this region.

Introduction

All commercial cultivars may develop scab, and differences in susceptibility have only recently been recognized (Hughes, 1980).

Cultivars Kennebec, Russet Burbank (Canadian strain) and Leven (pedigree Katahdin U.S.A., 1936 x Orion Scotland, 1947) were grown within commercial crops at 6 sites of low inoculum potential and one site of high potential. Soils were clay loams, of pH 5-6. At low inoculum sites, seed of the 3 cultivars were mixed and grown, with two harvests before maturity and one at full maturity. The cultivars were planted separately at the high inoculum site in randomized plots of 4 rows x 10m, replicated 7 times; harvests were at the maturity of the latest maturing (cv. Leven) and 9 weeks later after in-ground storage. A water budget and soil temperature records were maintained at the high inoculum site.

Tubers were harvested by variety, washed and sorted for disease severity; cultivars were compared as percentage weight with more than 1% surface area affected (low inoculum sites) and more than 5% (high inoculum site).

At low inoculum sites, light infection developed on Kennebec and Leven from the earlier plantings; Kennebec was affected more than Leven at sites with low scab incidence but not more so at the site of moderate incidence; Russet Burbank was minimally infected at all sites (Table 1).

At the high inoculum site, a low proportion of Russet Burbank had more than 5% scab coverage and Kennebec had a high proportion with more than 5% scab; Leven took an intermediate position. Severity increase during in-ground storage (LSD = 4.9 at p = 0.01) (Table 2).

Table 1. Powdery scab incidence in low inoculum sites (% of scab greater than 1%).

Site and date of planting	Time of sampling 1/	% Tubers showing scab Kennebec	Leven	R. Burbank
Mckenna I 17/10	1	0(+)	0(+)	0
	2	16.53***2/	3.20	0
	3	22.39***	0(+)	0
Morris 18/10	1	0	0	0
	2	3.15	0.75	0
	3	20.43***	0	0
French I 13/10	1	9.34	3.45	0
	2	12.15***	0	0
	3	33.33(***)	32.31(***)	0(+)
French II 14/11	1	0	0	0
	2	0	0	0
	3	6.42	0(+)	0
McKenna II 1/12	1	0	0	0
	2	0	0.93	0
	3	-	-	-
French III 8/12	1	0	0	0
	2	0	0	0
	3	1.44	0(+)	0

1/ 1, 2 = immature tuber-harvests; 3 = mature harvest.
(+) = powdery scab present, but less than 1% surface area infected.
- = no data collected.
2/ **, *** = significantly greater than other varieties at P = 0.01, P = 0.001.
(*), (**), (***) = significantly greater than Russet Burbank at P = 0.05, 0.01 and 0.001.

Table 2. Powdery scab incidence in high inoculum site (% scab-greater than 5%).

Site and date of planting	Time of sampling 1/	% Tubers showing scab Kennebec	Leven	R.Burbank
Badcock 25/10	1	89.8**2/	59.3(**)	16.7
	2	94.9**	65.7 (*)	37.5

1/ Time of sampling: 1 = harvest at maturity; 2 = harvest after in-ground storage.
2/ See footnote 2/ Table 1 for significance levels.

Discussion

Infection by Spongospora subterranea occurs largely during the 3-4 week period that follows tuber initiation (Hughes, 1980). Ware tubers are produced by the primary tuber initials soon after plant emergence, over a period of 3-4 weeks, and only 2 tubers/stem ever exceed 1 cm diameter (Grice, unpublished). The times of tuber initiation (TI) and the start of tuber growth (TG) are dependant on day lenght, insolation and temperature (Sands et al., 1979), and varietal differences are relatively small (Radley, 1963). It was therefore concluded that approximately equal opportunities occurred for the infection of the three cultivars in the trials.

The earliest plantings on areas of low inoculum and the trial at the high inoculum site experienced several occasions when soil conditions were favourable for infection at the time of tuber initiation and early growth. Such occasions appear on the water budget for the high inoculum site as the times of high soil moisture following irrigation and rainfall, when soil temperatures were relatively cool (13-15°C) during early December.

These considerations permit the conclusion that Kennebec always developed more scab that Russet Burbank (and to a lesser extent more scab than Leven) because of varietal differences in susceptibility. It is postulated that resistance may be related to thickness of the epidermis at TI/TG. Kennebec is more prone to skin wounds during harvesting than are the other cultivars. The russeted skin of Russet Burbank that commonly is developed at an advanced stage of tuber growth is an additional thickening to the normal epidermis, but it is not a necessary feature for resistance because Leven is a smooth skinned cultivar.

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USE OF TISSUE CULTURE TECHNIQUE

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Abstract

Utilization of present and future possibilities of tissue culture techniques for potato improvement now difficult to achieve by conventional means are discussed.

Introduction

During the last 50 years, tissue culture has become an important tool for vegetative propagation and freeing plants from pathogens. In recent years, new techniques have been developed that made it possible to obtain combinations of nuclear and/or cytoplasmic genes whose combinations by conventional methods is either

difficult or time consuming (Melchers 1977). Following are some techniques and their application:

Overcoming of crossability barriers

a) Sexual combination

In the search of resistance to diseases and adaptation to specific environments, distant wild relatives of crop plants are gaining importance in breeding. However, crossability and compatibility barriers present a serious, often time consuming, obstacle for the utilization of these species.

The breakdown of the fertilization process - incompatibility in the case of closely related material and incongruity in the case of wide crosses (Hogenboom, 1973) - may occur at distinct stages of this process (Heslop-Harrison, 1978). When early processes, such as germination of pollen grains on the stigma or penetration of pollen tubes into the style, are inhibited, in vitro fertilization followed by bud or ovule culture, may overcome this barrier. In this technique, the whole bud, the ovaries or isolated ovules are exposed to the pollen in culture. Meager work has been done in this field (Rangaswamy, 1977; Zenkteler, 1980). The conditions, under which development of potato ovules fertilized either in vivo or in vitro may be achieved, are being studied. When incompatibility or incongruity are responsible for unbalanced development or disturbed function of the endosperm, embryo culture may be a way to avoid this problem and the combination of new genotypes and the development of viable plants may become possible.

Successful embryo culture has been reported for several crop plants (Raghavan, 1977). Haynes (1954) reported successful embryo culture in potatoes using seeds obtained 20 days after fertilization. However, these seeds germinated also under conventional conditions; plants were also obtained through embryo culture from seeds which did not germinate (Upadhya and Chandra, 1977a).

b) Somatic combination

The union of two somatic cells by protoplast fusions leads to the combination of the whole set of both nuclear as well as cytoplasmic genes.

The protoplasts that fuse may have had their origin in different genotypes (heterofusion) or, they may have come from the same genotype (homofusion). Only heterofusion is obviously of interest to the plant breeder. The difficulty is to distinguish heterofusion from homofusion products and to recognize such colonies that developed from single protoplasts. Several methods to detect heterofusion products have been developed mainly by making use of genetically complementing partners. It has been shown that two different chlorophyll deficient mutants can be combined to give perfectly green colonies because the mutation locus is not the same in both genotypes (Melchers and Labib, 1974).

Consequently, the homofusion products as well as colonies developing from single protoplasts would always show the deficiency. Another case is the combination of protoplasts with resistance to two different toxins, only the heterofusion products grew in a medium containing both toxins (Dudits et al., 1979). It was also shown that only heterofusion products grew in a specific medium when two mutants with different blocks in the biosynthetic pathway of an essential metabolite were utilized (Glimelius et al., 1978). Another possibility is to use starting material whose protoplasts are morphologically sufficiently different so that heterofusion products can be isolated under the microscope (Gleba, 1978).

Intergeneric combinations have been produced through these techniques. For example, potato has been combined with tomato (Melchers et al., 1978), and Brassica with Arabidopsis (Gleba and Hofmann, 1979). In potato breeding protoplast fusion is being used to combine different resistances (Wenzel et al., 1982).

With regard to response to tissue culture, there are significant differences between genotypes in potato. In some clones, in vitro embryo development from anthers as well as successful protoplast culture and subsequent regeneration of plants from colonies and callus have been reported. Other genotypes completely resisted the same treatment, even if culture and media conditions were altered (Irikura, 1975; Simon and Peloquin, 1977; Sopory et al., 1978).

Shepard and Totten (1977) developed a system which was useful for some potato varieties and, with small modification, for other species as well. They emphasized the importance of preculture of the material for successful protoplast culture. Using CIP breeding material, the method of Binding et al., 1978, was modified to obtain viable protoplasts (International Potato Center Annual Report, 1981).

In a successful fusion experiment, protoplast fusion is followed by fusion of the nucleus, and orderly cell division will depend on the cytological and genetic relationship of the fusion partners. During the period from protoplast fusion to plant regeneration, genome rearrangements such as endopolyploidization, chromosome elimination and chromosome restitution may take place and lead to genetic variation. If unrelated species are combined, the elimination of the chromosomes of one partner often occurs. Nevertheless, it has been shown by DNA-hybridization studies that incorporation of small pieces of the eliminated chromosomes into the partner chromosomes takes place (Dudits et al., 1979).

Selection of variants and mutants at the cellular level

In several plant species, which have been used in tissue culture experiments, genetic variations were observed in plants regenerated from callus and colonies originated from single cells of the same somatic tissue (Larkin and Scowcroft, 1981).

Thus, characters expressed at the cellular level, occurring naturally or induced, may be selected for in vitro. Until now, most of this work has been carried out with either suspension culture or with mechanically isolated cells from leaf tissue (Kohlenbach, 1966; Schwenk, 1981), and this may well be an easy method to screen large populations for specific characters. It has been reported that genetically variable potato plants were isolated from protoplast derived colonies (Matern et al, 1978). The advantage of in vitro selection is to identify variant genotypes in a large population by adding the selection factor to the medium.

It has been possible to regenerate plants that showed higher resistance to a given stress factor than the control when they have been selected in vitro in the presence of the growth limiting factor. The stresses that have been used were salt (Nabors et al., 1980), herbicides (Chaleff and Parsons, 1978) and toxins from pathogens (Carlson, 1973). Berlyn (1980) selected colonies which grew in the presence of isonicotinic acid, an inhibitor of the glycolate pathway, to find plants with reduced photorespiration. In potato, colonies resistant to Phytophthora toxins (Behnke, 1979), methionine analogues (Chandra et al., 1981) and to toxic level salt concentrations (International Potato Center, Annual Report 1980) were isolated. Whereas plants have been regenerated from the toxin resistant colonies, plants have not yet been obtained in two latter cases. Plants regenerated from the toxin resistant colonies showed also some resistance to the pathogen.

Ploidy level manipulation

Ploidy level manipulations are an important breeding tool. Haploid or homozygous diploid plants permit rapid screening as recessive characters become exposed. The doubling of chromosome numbers becomes important in potato breeding when interploidy crosses lead to the abortion of the embryo through genetic imbalance in the endosperm (Johnston et al., 1980). Also, fertility may be restored in the case of amphidiploid chromosome combinations, which is important in wide intergeneric crosses.

Microspore culture, either inside the anther or with isolated microspores is a well established method which may lead directly to embryos or to callus from which plants can be regenerated. The products are haploids, homozygous diploids (when endopolyploidization has taken place at an early stage), or heterozygous diploids when the embryo or callus have been derived from somatic tissue which is possible if anthers are cultured. In the case of potato, many anther derived homozygous diploids and a few haploid plants have been obtained (Sopory et al., 1978). As in the case of protoplast culture, strong genotype dependence with regard to "cultureability" was reported.

Induction of adventitious buds in potato may lead to changes of the ploidy level (Roest and Boekelmann, 1968; Upadhya and Chandra, 1977b; Hermsen et al., 1981). Some genotypes produced considerable numbers of plants with doubled chromosome number.

For breeding purposes it is important that buds originated from one or only a few cells to avoid the formation of chimaeras. This was demonstrated by treating the tissue with mutagens before adventituous buds were induced. In the resulting plantlets a low percentage of chimaeras was obtained (Van Harten et al., 1981).

Transfer of genetic information

a) Cytoplasms-nucleus

Protoplast fusion allows the combination of genotypes whose combination is not pos-

sible by conventional methods. Apart from the combination of nuclear genes, those of the cytoplasms are also combined which does not usually happen in sexual combinations. The use of miniprotoplasts, which are nuclei or organells surrounded by plasmalemma and of cytoplasts, which are enucleated protoplasts (Wallin et al., 1978), may be a useful method for the study of interactions of nuclear genes with different cytoplasmic environments.

b) Organells

Nuclei, plastids, mitochondria, cytoplasmic factors, chromosomes and algae have been used for combinations with protoplasts of different origin. In most cases the uptake was induced by treating protoplasts with polyethylenglycol (PEG), and processes similar to pinocytoses take apparently place (Davey et al., 1976; Ueda et al., 1978). However, the organells usually deteriorate. The use of miniprotoplasts and nucleated or enucleated protoplasts (Wallin et al., 1979) may be more useful for such purposes. The other method under investigation is the incorporation of organells into lipid vesicles which are taken up by protoplasts in the presence of PEG (Matthews et al., 1979; Nagata, 1981). The incorporation of chromosomal segments, as reported in the case of plants regenerated from fused protoplasts of different species (Dudits et al., 1979), could be useful if the transfer of only a few specific genes is required. The use of protoplasts, which have been irradiated with high doses of X-rays to "pulverize" their DNA, may also achieve this aim (Dudits et al., 1980).

c) Isolated genome pieces and genes

The new technology, made possible through the availability of an assortment of restriction enzymes and through the cloning of DNA in E. coli, facilitates the transfer of genetic information (Sowokinos, these proceedings). The most developed system for plants is probably that which uses the Agrobacterium tumefaciens (A.t.) plasmid as a vector for genes. Virulent strains of A.t. produce tumors in plant wounds. The genes for tumor induction are situated on the same plasmid as the "opin"-gene which codes for an enzyme complex (lysopin-dehydrogenase, LpDH) that takes part in the synthesis of amino acids which are usually not produced in the plant itself. Three important steps towards a practical utilization of this fact have been taken:

1. Incorporation of the plasmid DNA into the plant genome was shown by DNA hybridization techniques. A specific region is incorporated when tumor induction occurs (Chilton et al., 1977).

2. Some part of the plasmid -"opin"-gene was replaced by an E. coli gene, coding for resistance to the drug methotrexate. Plants inoculated with A.t. containing this plasmid produced tumors, from which cells were isolated which grew in the presence of this drug in contrast to untreated controls (Hernalsteens et al., 1980). This shows that the E. coli gene had been transferred to and was expressed in the plant cell.

3. The A.t. plasmid was treated with mutagens, and plants were inoculated with A.t. carrying the mutant plasmid. From the tumors which developed, a few plantlets were regenerated. LpDH was used as a marker for the presence and expression of the plasmid genes, and these plants were LpDH positive. One of them was selfed, and the seedlings were tested for LpDH, 70% turned out to be positive. Anthers of the same plant were cultured and embryos developed, 40% of the plants that were regenerated from these embryos were LpDH positive. Then protoplasts were isolated from the same plant and cultured, and all of the regenerated plants were LpDH positive. Further crossing experiments showed that these genes act as single dominant Mendelean genes (Otten et al., 1981).

This proves that parts of the A.t. plasmid were incorporated into the plant genome and that these plasmid genes are transmitted to sexual as well as asexual daughter generations. It shows further that genes of one organism may replace those of another organism and that the newly incorporated gene is expressed in its new organism.

Thus, the A.t. plasmid serves as a reliable vehicle for isolated genes. The difficulty which remains at the moment is the isolation of plant genes of agronomic importance. It may be easy, for example, to isolate the nitrogen fixation-nodulation genes of Rhizobium sp., which are also situated on a plasmid. Similarly, the genes coding for active hydrogen uptake (HUP-genes), which may be important for efficient nitrogen fixation (Hennecke et al., 1981), may also be isolated. Other plant genes such as the alcohol dehydrogenase gene in maize (Gerlach, 1981) and the hordein genes of barley have been isolated.

It will be important to designate agronomically important genes which can be isolated easily and to prepare the corresponding receiving cell for the transformation. Strong cooperation between breeders, molecular biologists and tissue culture biologist is necessary to achieve this aim.

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WIDENING OF THE GENETIC BASE OF THE POTATO FOR RESISTANCE TO BACTERIAL WILT (PSEUDOMONAS SOLANACEARUM)

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Summary

Solanum phureja has been used extensively as the only and so far best source of resistance to bacterial wilt in potatoes. However, its resistance is pathogen strain-specific and temperature sensitive. Good levels of resistance have been found in a few wild Solanum species. The possibilities of inter-specific breeding to improve the resistance already available from S. phureja are discussed.

Introduction

It is generally recognized that bacterial wilt is one of the most serious constraints of potato production in tropical and subtropical regions.

A large body of literature about the complexities of this pathogen and how to control it exists, and present knowledge, which is the result of many years of research, permits summarizing the problems in one short paragraph.

Like most other pathogens, Pseudomonas solanacearum exists in a variety of races and specific strains with varying degrees of pathogenicity within each race. The classification system itself is an expression of the complex nature of this pathogen. The virulence of each strain depends upon specific environmental conditions, chiefly temperature and soil humidity or the degree of salinity of a given soil, to mention but a few. Other hosts, especially Solanaceae, play an important role for the survival of the pathogen in the soil which in turn may depend on cultural and agronomic practices. Interaction with other pathogens, such as root-knot nematodes, is well documented (Jatala and Martin, 1977a, 1977b).

In the genepool of cultivated potatoes, resistance to Pseudomonas of any consequence has only been found in the primitive diploid species Solanum phureja. Almost all known resistant lines or released varieties have been bred from clones of S. phureja. Although the resistance derived from this species covers the whole spectrum of races and strains of the pathogen, there exists a highly specific pathogen-environment-host-interaction, and the resistance is only expressed under relatively cool temperature conditions. It has not been possible to breed clones for all places where the problem exists, particularly the hotter and more humid areas in the world where potato cultivation has started in recent years. As long as resistant varieties remain the only effective way to control bacterial wilt, it appears that the genetic base of the populations that carry the resistance genes has to be widened. Apart from the genes coming from S. phureja other sources of resistance should be included in the populations which constitute until now the main pool of resistance to bacterial wilt.

Breeding strategy

It is a generally accepted principle in genetics that resistance to a particular pathotype which evolved in different species has a different genetic base in each species, or, in other words, the resistance genes in one species are different from those in another species although both provide resistance to the same pathogen.

Following this basic principle, the International Potato Center (CIP) has developed three different breeding populations with resistance to bacterial wilt. Only one of them, the oldest and most highly developed, is available for export at this time.

The first group has the internal code A_1 and consists of a fairly large population of well-performing families with a broad spectrum of resistance which is based on the resistance of the Colombian S. phureja clones which were first identified to have resistance to bacterial wilt. This population has also some resistance to Phytophthora infestans and PVY and most clones are early maturing and well-adapted to hot tropical conditions.

In order to broaden the resistance of this group to bacterial wilt, new sources, derived from S. raphanifolium and S. chacoense, have been incorporated into it. At present about 2000 seedlings of the latest cycle of selection are being tested in La Molina, and this material will be ready for export once the well-performing and resistant families have been identified.

The second group has the code TD and was derived from tetraploid x diploid crosses. The diploid parents were part of a population consisting of the two wild species S. chacoense and S. sparsipilum and the cultivated species S. phureja. All three of these species have lines with proven high levels of resistance to bacterial wilt. The tetraploid parents came from a popula-

tion with adaptation to the lowland tropics which has also been selected for earliness. In total, 343 clones from 75 families were grown under hot conditions in a field in La Molina and then evaluated for yield and agronomic characters. Initially, 52 clones were selected and replanted later. In the second round of evaluation and selection, only 19 clones from 14 families were retained. In spite of the fact that in some cases two genomes were contributed from a wild parent, excellent tuber shape and yields of up to 1.45 kg/plant were recorded. The average yield of the population finally selected for further breeding was 1.338 kg/plant. The best performers of the TD group have been inter-crossed with group A_1, and we have now a population growing which should combine resistance from four different sources.

It should be pointed out when considering the good yields and excellent performance of the TD hybrids that this is a result of breeding work in the diploid wild population before it was used for crosses to the desired tetraploid parents. These results indicate which route further breeding work with wild species should take.

Bearing the positive experience with the TD hybrids in mind, the original population of bacterial wilt resistant diploids was also maintained and developed further. Here is a brief history of this population: Resistant accessions of S. sparsipilum, S. chacoense, and S. phureja were merged into one panmictic population at CIP and 11,500 seedlings belonging to 11 families were tested against 4 and sometimes 5 strains (of races 1 and 3) of Pseudomonas solanacearum. Only 40 clones belonging to eight families survived the rigors of this testing which took almost two years. These 40 clones were intercrossed in more than 200 different combinations, and of the 100,000 seeds obtained, 10,000 seedlings were raised and tested against the particularly severe strain 013 of race 3. Some families showed survival rates of up to 67% which is a significant increase over the 30% recorded in the base population when it was originally assembled and tested against the same pathotype.

For the time being, these three genetic groups with various sources of resistance to bacterial wilt will be kept separate and developed further individually. This is particularly necessary for the group consisting of pathogen tested clones which may be exported from Peru. However, subsamples of each group will be merged into one breeding population which will eventually have four or more sources of resistance to the pathogen.

The wild group in particular will not only be tested for its resistance to the pathogen in each cycle of recurrent selection, but attention will also be paid to agronomic characters, such as stolon length, tuber shape and size and yield. At a later stage of the program the glycoalkaloid content of the wild population will be considered.

Experience with tetraploid x diploid hybrids, which contain two genomes from wild species, indicate that it might be advantageous to start selecting for agronomic characters early on in the program still within the wild population. The setback which normally results from a wild x cultivated cross appears to be less when the wild material has been selected for agronomic characters such as stolon length and tuber shape. Some experiments with haploids, which have been derived from highly developed tetraploid material, are under way, and these haploids will be included into the resistant wild diploid population.

The ready access to a vast and highly variable genepool of largely untested wild germ plasm gives CIP a comparative advantage for carrying out this type of research.

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A GLOBAL TYPOLOGY OF POTATO DEMAND

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Summary

While much has been written about projected trends in food grain consumption in developing countries (IFPRI, 1977), research on the demand for potatoes is extremely limited (Scott, 1981). Yet, the need for such information appears increasingly important because the potato's potential as a food crop for the Third World has been seriously underestimated (Horton, 1980). This conference paper proposes a global potato typology as a basis for future demand research. It focuses exclusively on the data, methods and results generated by the global potato typology.

Introduction

During the last 450 years the potato has traveled from its ancestral home -Peru- to become a valuable source of nutrition all over the globe (Rhoades, 1982). Only recently, however, have CIP social scientists begun the enormous task of charting these travels (International Potato Center, 1978) and eventually trying to explain and to predict them. Rhoades (1981) was the first to propose a potato typology to encompass different parts of the world. His typology identified four types of potato production regions based on altitude, climate, and the nature of prevailing farming systems. Given the shortages of corresponding secondary data for Rhoades' production regions, however, his typology was essentially descriptive. Furthermore, it was, by intention, only concerned with potato production and only with developing countries. Poats (1981) later put forward a potato consumption typology. She used Rhoade's four regions, but then embellished this typology by field work in several developing countries. While agro-ecology also was a critical explanatory variable in Poats' framework, the role of the potato in the diet provided a novel dimension. Poats argued that the link between potato production patterns and existing consumption habits was a combination of custom, ritual, and price, and not simply a function of the laws of supply and demand. Although both these typologies continue to demonstrate their usefulness in answering certain types of questions, they were primarily, though not exclusively, concerned with intra-national agro-ecological regions. They were restricted to developing countries and mapped existing potato production and consumption patterns. In light of CIP's mandate to strengthen national programs, its growing responsibilities as an information center for the developed and developing world and its continued concern with changes in worldwide potato production and consumption, a truly global typology was necessary to complement this earlier work. This global typology should employ national statistics. It should include developed and developing countries. It should also incorporate measures of the rate of change in potato variables. An additional, operational goal behind developing a global potato typology was the desire to identify representative countries for subsequent case studies of potato demand.

Results and discussion

In generating this typology, we went back to the FAO data that had proved so useful in identifying the potato's spectacular performance relative to other food crops during the previous two decades (Horton, 1980). We then added time-series statistics for trade, utilization, and consumption with the period 1964/66 to 1975/77 being the years for estimating global changes in potato consumption on a country-by-country basis.

After eliminating countries with little, e.g. Antigua or no, e.g. Bahrain recorded potato production and/or consumption, we used cluster-mean analysis to identify groups or clusters of countries according to the means of twenty-two uncorrelated indicators. After breaking up the countries into various configurations, we eventually settled on four clusters. (Table 1).

We then added a set of general socioeconomic variables, based on World Bank Statistics, to the potato indicators. By using discriminant analysis--first with the potato variables, then with the combined data set--we identified a total of seven significant variables to distinguish the four groups of countries. These variables and their group means are listed (Table 2).

Several observations could be made concerning these results, but only two will be emphasized here. Firstly, the four groups of countries, instead of four agroecological zones, fall on a continuum of higher to lower levels of production and slower to faster rates or urbanization. Most importantly, the composition of the groups that make up points on the continuum indicates that some developing countries - specifically the Andean group - may have far less in common with the rest of the developing world than studies related to ecology, custom, or relative income levels alone might otherwise suggest.

Secondly, this typology serves as one basis for beginning to assess the future course of worldwide potato production and consumption. These developments certainly will strongly determine the location and

Table 1. Global typology of potato demand.

Group 1.
Super high production countries

German Democratic Republic	Ireland
Holland	Poland
	U.S.S.R.

Group 2.
High production countries

Argentina	Italy
Albania	Korea, Democratic People's Republic of
Australia	
Austria	
Belgium-Luxemburg	New Zealand
Bolivia	Norway
Canada	Peru
Chile	Portugal
Colombia	Rumania
Czechoslovakia	Rwanda
Denmark	Spain
Ecuador	Sweden
Finland	Switzerland
France	Turkey
Germany, Federal Republic of	United Kingdom
Greece	U.S.A.
Hungary	Yugoslavia
Iran	

Group 3.
Low production countries

Afghanistan	Kenya
Albania	Korea, Republic of
Algeria	Libya
Angola	Madascar
Brazil	Malawi
Bulgaria	Malaysia
Burma	Mexico
Burundi	Mongolia
Cameroon	Mozambique
Central African Republic	Nepal
Chad	Nicaragua
China, People's Republic of	Panama
Costa Rica	Paraguay
Cuba	Philippines
Dominican Republic	Saudi Arabia
Egypt	Senegal
El Salvador	Sri Lanka
Ethiopia	Sudan
Haiti	Syria
Honduras	Tanzania
India	Thailand
Indonesia	Trinidad and Tobago
Iraq	Tunisia
Israel	Uganda
Jamaica	Venezuela
Japan	Zaire
Jordan	Zimbabwe

Group 4.
Low production, potato Trading countries

Guatemala	Mauritania
Hong Kong	Morocco
Ivory Coast	

strength of the demand for new potato technology. For example, the results listed in Table 1 suggest that Group 3 countries are more likely to increase per capita potato consumption of potatoes in the years ahead than Group 2 countries. Future work on the individual groups themselves and countries within those groups will begin the task estimating the magnitude of these increases.

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NEW APPROACHES FOR CONTROL OF BACTERIAL WILT OF POTATO

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Bacterial wilt of potato, caused by *Pseudomonas solanacearum* E.F. Smith, continues to be a major factor limiting potato production in many areas of the world. This is exemplified by the relatively recent, serious outbreaks of bacterial wilt in Mexico, Uruguay, Argentina, etc. The use of resistant varieties, developed within the last 10 years, has given a measure of control in the highland areas where cool mean temperatures prevail. As the range of the potato is extended to the warmer areas, however, it is evident that bacterial wilt will have to be controlled by means other than those presently available. It is most appropriate that, in concert with the theme of this Decennial Anniversary, "Research for the Potato in the Year 2000", we include consideration of some potential means for control of bacterial wilt that may become a reality in the foreseeable future. The intent of this session is to stimulate discussion on new methodology for control; thus, my remarks are not based on a great deal of actual experimentation and are presented here mainly as ideas that may be used as a basis for possible recommendations to the International Potato Center for future action.

Conventional breeding procedures have been used to provide us with a number of useful cultivars derived from crosses of *Solanum phureja* x *Solanum tuberosum*, or *S. phureja* x *S. andigenum* (Sequeira, 1979). Although it is clear that we have not utilized all of the dominant genes that confer resistance to *P. solanacearum* in certain *S. phureja* clones, we know that even the most resistant clones (e.g. CC 1386.15) do not withstand stem inoculation when maintained at constant, high temperatures (e.g. 32°C). Unusually vigorous hybrid clones with *S. andigenum* in their pedigrees (e.g. MS 35.22) appear to do well at relatively low elevations in the tropics (Jackson and González, 1981) but only when race 1 is the primary component of the population of the pathogen. My overall impression is that we must search for additional sources of resistance and, fortunately, resistance to *P. solanacearum* is widespread among the tuber-bearing species of *Solanum*. The extensive attempts presently being made to utilize resistance from *S. sparsipilum* and other wild sources may ultimately provide us with appropriate sources of resistance for the lowland tropics, as indicated in the contributions by Dr. Martin and Dr. French at this session.

One potential problem with the breeding approach is the extreme variability with *P. solanacearum*. Most resistance factors whether in potato, tobacco, or tomato, appear to be controlled by relatively few dominant genes. Even in crops such as tobacco, where a single source of resistance has been effective for decades, there are indications that new strains of the bacterium are now able to overcome resistance in most commercial cultivars. Whether sources of horizontal resistance that are stable at relatively high temperatures will be found in wild species of *Solanum* is still an open question. We must prepare, therefore, for the possibility that conventional breeding methods will not provide a complete answer to the problem of resistance in potato to bacterial wilt. It is for this reason that, at Wisconsin, we are beginning to explore some alternative approaches to control.

Our emphasis now is on biological control. This type of control offers many advantages, not the least of them being the low cost, persistence, ease of application, and the biodegradability and safety of the biological agents. The disadvantages of biological control are obvious; there are relatively few examples of success in the literature, possibly due to the highly variable nature of the effects that are obtained and the extreme influence of environmental factors, such as temperature and humidity, on the control agents. The recent successful application of biological control for the crown gall disease, however, suggests that in specific instances the disadvantages of biological control can be overcome (Kerr and Htay, 1974).

Table 2. Mean values of variables which distinguish groups of potato countries.

Group	N 1/	Consumption/capita 1975/77 (kilos) 2/	Compound growth production 1961/65-1975/77 2/	Compound growth imports 1961/65-1975/77 2/	Exports as % of supplies 1975/77 2/	Production/capita 1975/77 (kilos) 2/	Potato area as % crop area 1975-77 2/	Growth urban population 1960/70
1	5	122	-0.5	96.3	5.2	508.9	19.8	1.9
2	30	63	0.6	12.2	2.3	106.4	5.2	2.9
3	55	9	4.6	-12.0	1.1	11.6	0.8	4.6
4	5	4	89.7	-14.5	18.4	6.3	1.1	8.1

1/ Number of countries. (Six countries were not classified into a particular group by cluster analysis).

2/ Refers to potatoes.

Two types of biological control offer some promise for the control of P. solanacearum in potato. One is the use of antagonistic or attenuated strains of bacteria to induce systemic resistance in the host. The second is bacterization of tuber pieces with antagonistic or competitive rhizobacteria. These two methods are discussed briefly in the sections that follow.

Induced resistance

Plant pathologists have recognized for several decades that the potato plant responds to infection by physiological changes that may arrest the development of the potential pathogen. In particular, terpenoids that are either antifungal or antibacterial accumulate at the infection court when potato tubers are inoculated with incompatible forms of plant pathogens (Kuc et al., 1976). Of greater interest, perhaps, has been the demonstration that there are systemic as well as localized physiological changes that provide a surprising degree of non-specific resistance against a wide variety of pathogens (Sequeira, 1979).

In our laboratories, Ms. J. Kempe has attempted to induce resistance in potato to P. solanacearum by prior inoculation of tuber seed pieces with avirulent strains of this bacterium: B82, from strain 82, isolated from potato; B248, from strain 28, isolated from tobacco, and with a virulent strain, 80, isolated from banana. These strains presumably are incompatible in potato, although only two (B81 and 70) give a hypersensitive response on potato leaves. In addition, strains B82 and 70 produce bacteriocins in culture which are highly inhibitory to many other strains of P. solanacearum, including strain 276 which was used in the challenge inoculation. For comparison, we included two strains of Pseudomonas fluorescens (Pf and W163) which are saprophytes that do not induce systemic resistance but are highly competitive with or antagonistic to P. solanacearum.

Seed pieces of the cultivar Ontario were immersed in suspensions of these bacteria (10^5 to 10^8 CFU/ml) and then planted. Approximately 1 month later, the plants were inoculated with strain 276 by the stem puncture technique. In one experiment, plants from tubers treated with W63, B82 and 70 developed symptoms less frequently and more slowly than untreated plants or those treated with other bacteria. In plants treated with W163, no symptoms were evident even by 44 days after infection, but only when the plants were kept at relatively cool temperatures. When the experiment was repeated but the plants were kept at a constant 28°C after inoculation, only strain 70 gave a significant level of control. When similar experiments were carried out with cultivar Russet Burbank, rather than Ontario, no resistance was evident with any of the treatments. In fact, plants inoculated with strain 70 died before they reached the height necessary for challenge inoculation.

Several modifications for the original procedure have been attempted with Ontario tubers. In one, prior inoculation was attempted by injecting the buds rather than by dipping the entire seed piece. In this instance, both strains W163 and B82 gave a substantial level of control.

Although these preliminary results appear promising, we are as yet unable to predict when a particular strain will give a useful level of control. The use of a variety with an inherent, low level of resistance, such as Ontario, seems important. In addition, best results were obtained with strains that are able to multiply in the host to some extent.

Rhizobacteria

A relatively new procedure for biological control, not yet tested against P. solanacearum, is the use of seed treatments with bacteria (generally belonging to P. fluorescens or P. putida) that are particularly aggressive colonizers of the rhizosphere of the crop plant (thus the term "rhizobacteria"). The method was originally developed by Dr. M.N. Schroth and associates for the control of soft rot bacteria on potato (Burr et al., 1978, Kloepper and Schroth, 1981; Kloepper et al., 1980; Schroth and Hancock, 1981), but has been applied to other crops such as radish, sugar beet, lettuce, etc. which respond, in many instances, by remarkable increases in yield as compared with untreated controls. The yield increases appear to result from control of root pathogens as well as from the production of growth regulators and other substances that are favorable to plant growth (Schroth and Hancock, 1981). The emphasis on yield has tended to obscure the role that rhizobacteria may have in the control of other root-inhabiting bacteria, such as P. solanacearum. Although it is evident that P. solanacearum does not survive in the rhizosphere for long periods (Granada and Sequeira, 1981), it must be present there before it can infect the roots of either hosts or non-hosts. Because P. solanacearum is not a strong competitor in the soil and apparently survives in the internal root tissues, where it is protected from competition, it should not be difficult to isolate bacteria that aggressively colonize the rhizosphere and thus displace P. solanacearum and other plant pathogenic bacteria.

The use of rhizobacteria appears to be particularly promising because of their highly persistent nature. Once they are applied to potato seed pieces, perhaps in dry powder form, and the seed is planted in moist soil, rhizobacteria should colonize the root surface of the developing plants and remain there until harvest. Such long-lasting colonization with the proper bacterial strains should result in effective control of P. solanacearum. Research should be initiated as soon as possible to select the most efficient strains of rhizobacteria from tropical soils.

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THE ROLE OF THE POSTHARVEST INSTITUTE FOR PERISHABLES (PIP) IN POTATO MARKETING SYSTEMS IN DEVELOPING COUNTRIES

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The Postharvest Institute for Perishables (PIP) was founded at the University of Idaho a little more than a year ago for the purpose of identifying the causes of postharvest losses and developing methods for their reduction in vegetables, fruits, roots, tubers, oil seeds, nuts, and spices in developing countries. The potato, as a tuber crop, receives much attention in PIP because its area of cultivation is increasing in the developing countries, and it clearly appears that this trend will continue in the years to come.

There are numerous postharvest loss problems associated with potato production and marketing, and it is reasonable to expect that these problems will increase in proportion to expanding areas of cultivation. In addition, new postharvest problems may appear as a result of the development of new potato cultivars adapted to environments that were previously minimal or subminimal for potato production. These problems may involve diseases, insects, short term or long term storage ability, chemical changes during storage, or various other factors.

There are many highly qualified specialists around the world who are directing their research to the solution of specific postharvest problems in potatoes. The success of their efforts over the years can easily be measured by comparing, for example, the cooking, baking, storage, or nutritional characteristics of today's cultivars with those grown a few years

ago. Nevertheless, these specialists continue to set higher standards for the characteristics of potentially new cultivars, and new avenues of research, such as genetic engineering, encourage those in research to focus greater efforts on specific postharvest problems.

In developing countries many of the postharvest problems in potatoes are related to the transition from the traditional subsistence farming to production for a market. This, in many cases, is directly related to the transition from an agricultural to an industrial economy in those countries. This transition has been unfolding for many years and will likely continue for many more years to come. The farmer who previously produced primarily for his own needs and sold or bartered a small surplus amount now has the incentive to produce primarily for a growing, urban, industrial population.

As a consequence of this incentive, farmers are attempting to satisfy the market demand, but in many instances they are not introducing high quality produce into the marketing channels that will terminate at the consumer level. There are undoubtedly various complex reasons for this situation, but they probably originate primarily from a lack of knowledge of what the market demands, i.e. quality, quantity and timing of consumer desires, and the characteristics or techniques of production, handling or processing that will allow potatoes to progress through the market with the least amount of deterioration.

In most countries commodity price does not necessarily signal needed changes. Therefore, the farmers or producers are not aware of problems beyond the farm gate that could be reduced if the farmers were to change their practices for the purpose of controlling postharvest losses. Another significant factor is that the farmer probably lacks the finances and facilities to implement the necessary improvements.

It is axiomatic that a high quality product must leave the farm if a high quality product is to reach the consumer. Similarly, any quantitative or qualitative damages done to the crops are cumulative through the various phases of the marketing chain, and are also irreversible.

Usually the first steps in the postharvest life of a crop are simple packaging and storage on the farm in preparation for shipment to market. All too often it is also at the farm level where the first factors occur, such as rough handling and bruising, poor packaging, and poor temporary storage conditions, that contribute to the early deterioration of the product.

After the crops leave the farm they may be rehandled, repackaged, shipped and stored several times before they reach the consumer. And at each stage further deterioration may occur as a result of improper handling, packaging or storage. Throughout this chain, therefore, damaging events may occur that have a serious effect on the final quality or quantity of the product, and all too often the individuals responsible for those events are unaware of their magnitude or ultimate effect. This, again, frequently relates to a lack of knowledge or an inability to effect any change.

Unfortunately, it is often seen that the application of known and established technologies to a specific postharvest problem, such as proper long-term storage conditions for potatoes, may have minimal effect on improving the quality of the product that reaches the consumer. This is because all phases of the marketing chain are very closely related, and no one phase can be treated as an isolated event. Superficially it might appear that the scientific studies done in other places and times to develop the proper storage conditions were faulty, but that usually is not the case. Nevertheless, the latter must be taken into consideration. Not so much because the scientific work was faulty, but because the parameters may vary because of differing environments, growing conditions, cultivars or other factors.

It is a consequence of the close relationship that exists between all phases of the marketing chain that PIP has emphasized the development of a capability to analyze the entire marketing system when the Institute initiates a study of a postharvest problem. Not infrequently, unidentified or unrecognized predisposing factors have a greater effect on later crop deterioration than any identifiable factors at the point where loss is seen or measured.

Furthermore, it is quite likely that broad analyses of market systems will be in greater need in the years ahead as developing countries progress from subsistence farming to farming in order to supply an urban market some distance away, and then to production for an export market where the efficacy of a good postharvest handling system receives its maximum test.

When PIP completes a detailed analysis of the entire marketing system where postharvest losses occur, several valuable purposes are served:

- Isolation of the various points in the market channel where losses occur.
- Development of a concept of the importance of various causal factors of losses in relation to the whole.
- Application of a methodology for loss assessment provides the basis for determining priorities in a loss reduction program.
- Providing information relative to the impact that could be realized from the application of appropriate technology to specific loss points in the market channel.
- Defining areas where long-term research is indicated.
- Obtaining data or other information to be used in future training of individuals or organizations involved in the entire marketing system.

With this information a well-designed postharvest loss reduction program that concentrates systematically on the indicated points in the marketing channel can be initiated. An analysis of the information can be made by various organizations or entities, such as regional or national governments, multilateral donor organizations, or private sector interests in order to determine their points of entry into a program that would include postharvest loss reduction as one of its objectives.

Concerning training, the information can provide a strong and vital basis for demonstrating to the people involved in the channel - whether production, handling shipping, packaging, storage, distribution or retailing - the importance and value of their individual contributions toward reducing postharvest losses.

In addition to these immediate benefits derived from marketing studies, there may be long-term benefits with scientific, social or economic importance. The need for new long-term research may be revealed that could have far-reaching effects. Also, the effective reduction of postharvest losses in a crop such as potatoes creates an atmosphere conducive to exporting in the natural or a processed form. This, of course, can have very positive effects in many sectors of a national economy.

Participants may obtain literature which describes in greater detail the operations and facilities at the Postharvest Institute for Perishables, as well as a representative sample of a literature search, and the means for obtaining more information by writing to the above address.

RECOMBINANT-DNA TECHNOLOGY AND IMPROVEMENT OF POTATO QUALITY

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Abstract

Recent developments in molecular biology and recombinant-DNA technology in prokaryotic bacteria have led to a surge of interest in plant-cell research. At present, however, direct "genetic engineering" of plants themselves is still primitive when compared to achievements with microorganisms. Of more immediate application is the molecular cloning of plant-DNA in bacteria. The associated techniques of molecular biology have already contributed new information on the structure of plant genes and on the molecular nature of genetic variation. This article is concerned with identifying research areas that need exploration before recombinant-DNA technology can be efficiently utilized to improve potato quality in the 21st century.

Introduction

Techniques of *in vitro* DNA recombination and transfer consist of four stages as follows: a. selection of genes and vectors of interest, b. preparation for splicing the gene of interest into the vector, c. insertion and maintenance of the recombinant-vector in a suitable host and d. selection of the desired clone (Dally *et al.*, 1981). Just how soon "genetic engineering" techniques can be used to improve quality of complex eukaryotes, such as the tetraploid potato plant, will depend not only upon technological advancements during the next 18 to 20 years but also upon economic considerations. The growing demand for food and other agricultural products should be ample practical justification for undertaking the enormous research effort that will be needed to apply the techniques of DNA transfer to create improved variety types.

State of Art - Year 1982 to 2000

The latest strategy in applying microbiological techniques to traditional agricultural practices has been the introduction of foreign DNA into plant cells (Brill, 1981). This practice could open

the way for direct genetic engineering of the plants themselves. Although efficient procedures for the transformation of plant cells have not yet developed, some success has been achieved by using cauliflower mosaic virus (CaMV) DNA and T_1 plasmid DNA from Agrobacterium tumefaciens (Postgate and Cannon, 1981). Both of these nucleic acid strands are potentially useful for vector construction. Scientific knowledge needs to greatly expand in four major areas of research before the sanctity of the potato cell nucleus will be beneficially altered by genetic engineering. These individual research areas are as follows:

a. Identification of potato genes of agricultural importance.
b. Isolation and characterization of the structure and regulatory properties of these genes and their gene products.
c. Identification of vectors (naturally occurring or chemically constructed) that are compatable with potato cells that can be spliced with the desired genomic segment.
d. Development of methods to effectively introduce the recombinant-vector into potato cells (i.e., cultured or protoplasts) and to identify regenerated plants that express the desired trait.

Major advancements during the remainder of the 20th century may result from insertion of various plant genes into bacteria. Subsequent growth of the recipient bacterium to form a clonal population of cells, from which plant-DNA can be reisolated, can provide large quantities of the pure plant-DNA sequence. With large quantities of pure DNA sequence, extensive studies, including nucleotide sequencing, can be carried out (Flovell, 1981). Important biological investigations have been initiated that may lead to an increase in photosynthetic efficiency. The large subunit of ribulose bisphosphate carboxylase from chloroplast genes of wheat and maize has been cloned in E. coli making the protein available for studies of its regulatory properties (Flavell, 1981). Other studies using microbiological techniques involve the insertion of nitrogen-fixing genes (nif genes) into yeast and cereal plants (Brill, 1981; Postgate and Cannon, 1981). Segments of chloroplast DNA have been mapped in a number of species including maize, pea, spinach, and wheat. Every segment has been cloned in bacteria and consequently large quantities are available to map and sequence (Flavell, 1981). Analysis of the structure of plant genes could aid in the eventual unraveling of the complex biological control mechanism regulating their expression at the molecular level.

Recent utilization of recombinant-DNA methodology has led to the development of a new method for screening large numbers of potatoes for spindle tuber viroid (PSTV) (Owens and Diener, 1981).

The development of new potato varieties which are higher in solids content would increase their value for processing markets as well as increase the caloric value of this innately well-balance food. Recombinant-DNA techniques are being considered for the gene which directs the formation of ADPglucose pyrophosphorylase in potato cells. The ADPglucose pyrophosphorylase gene has recently been identified as being of agricultural importance. Its gene product has been suggested to regulate solids formation or starch synthesis in potato cells (Sowokinos and Preiss, 1982). The gene for this enzyme in E. coli has been isolated and elucidation of its complete nucleotide sequence is near completion (Baecker et al., 1981). Initial studies with the potato gene would involve its amplification in E. coli followed by its reisolation. Large amounts of this specific DNA segment would permit nucleotide sequencing and other investigations given under research area B listed above.

Recombinant-DNA Technology and the Potato - The 21st Century

Many of the systems the plant molecular biologist explores that have some significance for yield, quality or resistance to disease and other stresses, are in modern terms almost unexplored genetically and biochemically (Day, 1981). Exceptions include the modification and improvement of certain grain storage proteins. Many diseases caused by viruses, bacteria, and fungi could be controlled by single major genes found in wild species. However, so little is known about the biochemistry of plant disease resistance that we can still only guess what the products of such genes are or what mechanisms are responsible for distinguishing between a resistant vs. a susceptible response. (Day, 1981) Future production of superior variety-types utilizing genetic engineering techniques, depends greatly upon the scientific contributions made in the four research areas listed previously. A few of the possible benefits that may ultimately evolve from such research in potatoes and other crops are: (a) introduction of resistant genes to prevent attack by pathogenic fungi and bacteria, (b) increases in key plant products, (c) increases in the resistance of plants to saline, high acid, heat, and cold stress environments, (d) insertion and expression of nitrogen fixation genes and (e) increases in photosynthesis efficiency, carbon assimilation and yield.

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NEW POTATO STORAGE TECHNOLOGY

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The potato, Solanum tuberosum L. together with other cultivated species of Solanum, is probably the most important and nutritious vegetable in the world today and its use and distribution is being expanded each year. In the past the potato was grown mostly in the temperate regions and at high elevations in the Andean regions, whereas, now potatoes are grown in regions as diverse in climate, photoperiod, and other growing conditions as those found north of the Artic Circle, in arid equatorial regions, and those of the tropical low lands.

The production and storage technologies employed in these diverse conditions, of necessity, must be different. However, storage anywhere has as one main objective - the maintaining of high quality, nutritious food material in an edible and useable condition over as long a period as is necessary.

The subject of "New Storage Technologies" should be persued from two distinctly different avenues:

1) new potato storage technology as related to the developed countries where power, chemical inhibitors, refrigeration, and capital outlay monies are available to store potatoes for extended periods for processing and fresh market, and
2) storage technology needed for the developing countries which may not necessarily involve new principles, but which would require the practical, inexpensive application of already known principles and technology to the conditions presently existing in the various developing countries.

Practical and proper transfer of this technology to the various and different situations existing in the developing countries today is one of the most important tasks facing us in the next few years.

Maintenance of proper environmental conditions within a potato storage by sophisticated air ventilation systems and proper management of fans, humidifiers, sprout inhibitors, and electronics using computerization and remote sensors are being utilized today to maintain the raw product in its highest state of quality over long periods of time. New advances are being made on types of insulating materials, where and how they should be applied to reduce refrigeration requirements, fire hazard, and how to protect these materials from climatic and mechanical destruction. Work at the University of Idaho Research and Extension Center at Aberdeen, Idaho show that application of polyurethane insulating material on the exterior of the building has reduced the heat transmission from the outside to the inside during the summer months (thus reducing the refrigeration requirement); has reduced the fire hazard; has reduced insurance rates; has reduced the amount of labor to apply the material in addition to reducing the amount of insulating material needed (no

purlins or beams to cover); and has reduced condensation because there are no metal to metal contacts with the outside climatic conditions.

Other new technologies being considered included solar cooling and refrigeration, new types of inhibitors and new methods and environments to reduce sugar buildup in potatoes destined for processing.

These new technologies will require a considerable outlay of funds, consequently are not readily adaptable to the developing countries today; however, many principles already available can be utilized by the developing countries with a minimum of capital outlay. One of these principles now being put to use in several countries is the use of natural diffused light for the storage of seed potatoes. Another is making use of diurnal fluctuations in temperature and evaporative cooling to minimize the temperature buildup due to respiration. Using the principle of cold air being heavier than warm air. Dig a pit under a slatbottomed storage (Figure 1) and, partially fill the pit with water. During the night the cold air would settle into the pit cooling the water and air under the storage. Then during the day unroll a wick material into the water and by evaporative cooling, cool the air which will be drawn up through the potatoes by convective currents. Also an evaporative cooling pool can be built in the roof of a storage. Ventilation can be accomplished by a man-powered fan (pedalled like a bicycle) which can force or draw cooler air up through the storage. It can be operated at night to take advantage of the cool night air and can be coordinated with evaporative cooling in the daytime.

These are only a few of the many ideas or principles that can be adapted for use by the people in the developing countries to maintain their potatoes in an edible and useable conditions for a period of time.

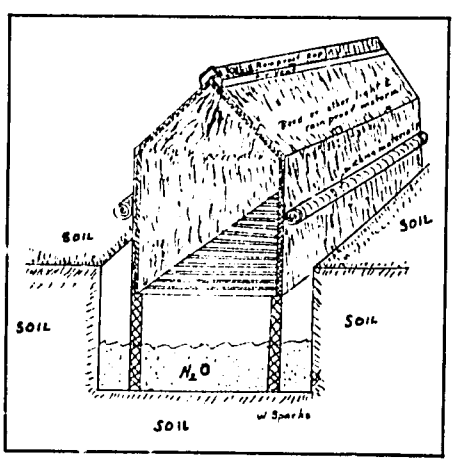

Figure 1. Simple storage for market (eating) potatoes.
Slatted floor for convective cooling. Reed sides (light proof to prevent greening. Cool air settles down into area under storage at night. During day wicking material unrolled into water. Evaporative cooling cools storage during day.

THE NATURE OF RESISTANCE TO POTATO CYST-NEMATODES

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Cyst nematodes are specialised parasites, presumably products of co-evolution with their hosts, a process which has tended to produce complexes of similar species and pathotypes within species (Stone, 1979). Pathotypes are defined as variants of a cyst nematode species which differ from others in their ability to multiply (virulence) on particular plant genotypes known as differential hosts, after the general definition of Robinson (1969). Virulence is defined as in Vanderplank (1978). The evolution of such relationships seems likely to depend upon the selection of major genes for resistance in the hosts and major genes for virulence in the nematode, acting according to Flor's gene-for-gene hypothesis. Parlevliet and Zadoks (1977) have argued that even in the case of polygenically based horizontal resistance a gene-for-gene action may operate.

Resistance to potato cyst-nematodes has been shown to be mediated by major genes in Solanum multidissectum (Dunnett in Gregor, 1963), S. kurtzianum (Huijsman, 1960), S. spegazzinii (Ross, 1962) and in several lines of S. tuberosum ssp. andigena (Toxopeus and Huijsman, 1953; Howard et al., 1970). Evidence that the gene-for-gene relationship does indeed govern interactions between potato cyst-nematodes and potatoes with major resistance derived from S. tuberosum ssp. andigena and S. multidissectum has been produced, (Jones et al. 1981; Parrott, in press). They demonstrated that in crosses between virulent and non-virulent pathotypes of the same nematode species, the numbers of hybrids produced on resistant plants were close to those expected if it was assumed phenotypes able to produce females were homozygous for a single recessive gene.

Of the sources of resistance to potato cyst-nematodes utilised in the last three decades, all except S. vernei have been identified as providing major genes, mainly conferring resistance against Globodera rostochiensis. In S. vernei resistance is believed to be mediated by polygenes (Goffart and Ross, 1954; Rothacker, 1958) or due to a complex of major and minor genes (Ross, 1969; Huijsman, 1974). Simmonds (1973, 1974, 1976) argued that this resistance was of the horizontal or field type and inherited polygenically. Much importance has been attached to the S. vernei sources and their hybrids because they provide resistance to G. pallida as well as G. rostochiensis, and because the resistance was believed to be non-pathotype specific. However, the partially pathotype specific nature of the resistance in hybrids of S. vernei (Kort et al., 1978) suggests that this is not so and we investigated this relationship further. If the resistance is mediated by several major genes then tests of the type used by Jones and Parrott are not practical and we have used a different approach, observing the changes in numbers of cysts produced on S. vernei hybrids when G. pallida populations were maintained on them for several generations.

Cysts of three G. pallida pathotypes (Table 1) were multiplied on two S. vernei hybrids, 62.33.3 and 65.346/19, which are resistant to some pathotypes and are partially resistant to others, supporting multiplication at a low rate but with Pf/Pi > 1 (Kort et al., 1978). At the start of each season an inoculum of 30 crushed cysts was added to single potato plants in pots. The new generation of cysts produced was extracted from the soil and dried after senescence of the potatoes, stored until the following season, and then inoculated as above onto the same clones on which they had been raised and onto Arran Banner, a fully susceptible S. tuberosum cultivar.

Treatments were replicated five-fold where possible. The process was carried out five times, giving counts of the F1 to F5 generations of cysts. Some populations did not reproduce sufficiently well to maintain selection throughout the experiment and were abandoned. Counts of cysts of each population recovered from each hybrid were expressed as a percentage of the grand mean for all populations on Arran Banner, and are shown (Figure 1) together with a fitted common slope. Significance of the linear regressions of these percentages on successive generations are listed (Table 1).

The increases observed suggest that selection for an unknown number of major virulence genes occurred in the nematodes and that the S. vernei hybrids must have corresponding major genes for resistance. The unselected populations we began with will have contained only a small number of individuals with genotypes including the virulence genes necessary for development on the resistant host but this number has been increased by selection. The rate of increase will depend on the number of resistance genes present in the resistant hosts and the frequency of virulence genes in the nematode populations. The varying, partial resistance of some S. vernei hybrids to G. pallida (Simmonds, 1976) is explained by this hypothesis.

The common slope gave a rate of increase of females in each generation able to reproduce on the resistant clones of O.1. J.N. Perry (unpublished) has simulated a population increasing at such a rate on a polygenetic host using the model of Jones and Perry (1978), with an initial proportion of females able to reproduce on the

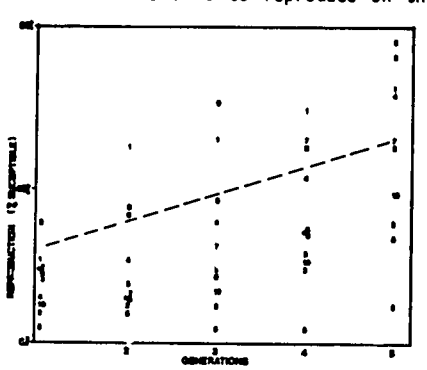

Figure 1. Mean counts in each generation of Globodera pallida populations selected on Solanum vernei hybrids, expressed as percentages of the mean of all populations in each generation on susceptible S. tuberosum. The broken line shows the common slope (i.e. rate of increase) fitted to the linear regressions derived from the data. See Table 1 for key.

Table 1. Globodera pallida populations selected for five generations on resistant Solanum vernei hybrids.

	Population	Pathotype	Hybrid	Regression significant at P =
1	Glarryford	Pa1	65.346/19	5%
2	Glarryford	Pa1	62.33.3	(10%)
3	LOC	Pa2	62.33.3	N.S.
4	Wainfleet	Pa2	65.346/19	1%
5	Wainfleet	Pa2	62.33.3	N.S.
6	Crowle (CA)	Pa2	65.346/19	N.S.
7	Crowle (CA)	Pa2	62.33.3	5%
8	Crowle (CH)	Pa2	62.33.3	N.S.
9	Frenswegen	Pa3	65.346/19	5%
10	Frenswegen	Pa3	62.33.3	5%

resistant host of 0.1 and an initial population density of about 5 eggs g^{-1}. A single generation was assumed each year. This was compared to a simulated population, with identical initial values, in Hardy-Weinberg equilibrium on a host with single gene resistance, allowing only doubly recessive females to reproduce. The latter population was initially selected more rapidly but after eight years there was little difference between the populations. After nine years the population on the polygenetic host was assumed to be fully selected and the two populations were virtually indistinguishable, both in numbers and in ability to reproduce. Selection of virulence against polygenetic resistance also occurred, but at a slower rate, when extended rotations of the resistant potato were modelled.

The G. pallida pathotypes currently recognised have been defined by their performance on S. vernei hybrids including 62.33.3 and 65.346/19, and characteristics of pathotypes will depend on the particular major virulence gene composition of the nematode populations chosen when the pathotypes were defined. Considering the heterogeneity demonstrated in G. pallida by our results it seems unlikely that all the field populations encountered will have the same combinations and frequencies of virulence genes as the populations used when defining the pathotypes. Because of this some field populations will not be clearly identifiable as single pathotypes within the current scheme.

In conclusion, theoretical considerations and experimental evidence suggest that in all cases resistance in potatoes to potato cyst-nematodes is dependent upon major genes and is pathotype specific. As additional sources of resistance are exploited further pathotypes will be recognised. The present pathotyping schemes (Kort et al., 1978; Canto and de Scurrah, 1978) which depend upon differentials endowed with multiple, unspecified resistance genes will fail to characterise some populations but until all resistance genes involved have been identified, a more precise classification is unlikely. Fortunately the biology and population dynamics of potato cyst-nematodes coupled with extended host-crop rotation do not favour rapid selection and spread of virulent genotypes but where such heterogeneity exists in field populations, resistance may have a finite life whether it is based on single or multiple major genes.

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THE ASSESSMENT OF ADENOSINE TRIPHOSPHATE IN POTATO CYST-NEMATODES BY BIOLUMINESCENT PHOTOMETRY AND ITS IMPLICATION FOR PCN-RESISTANCE SCREENING IN THE POTATO

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Summary

Dilution-counting of juveniles of potato cyst nematodes (Globodera spp.) is tedious, time-consuming and subject to operator-error. Measurement of nematode adenosine triphosphate (ATP) by bioluminescent photometry offers considerable potential in resistance screening programmes for the assessment of true multiplication rates of potato cyst nematodes on the potato.

Introduction

The potential for exploiting the relationship between the number of potato cyst nematodes (Globodera spp.) (PCN) and their content of adenosine triphosphate (ATP) as a method of counting nematodes has been suggested by Atkinson and Ballantyne (1977a, b) and examined in relation to soil fumigation practice by Bunt and Van Eck (1978), Storey and Atkinson (1979). This paper reports on the potential of the method for the rapid assessment of multiplication rates of potato cyst nematode in screening for resistance in the potato, by substituting ATP measurements for conventional visual dilution-counting of juveniles.

Results and discussion

An initial experiment, using an Aminco photometer and crude (firefly-tail) extracts of Luciferin-Luciferase enzyme to measure the reaction: Nematode ATP + Luciferin-Luciferase → Biolomuniscence, measured PCN-multiplication on two separate occasions on three clones of different susceptibilities to PCN grown in the laboratory (in closed containers) and in the greenhouse. Multiplication rates were adjusted for unhatched juveniles 'standard volumes' of cysts as a recoverable inoculum (Marks and McKenna,

1981) after 5- and 12-week host-contact periods. Although considerable variability was apparent between individual replicates within tests, the composite data for pathotypes Ro1 and Pa3 (Figure 1) were sufficiently encouraging to merit further work.

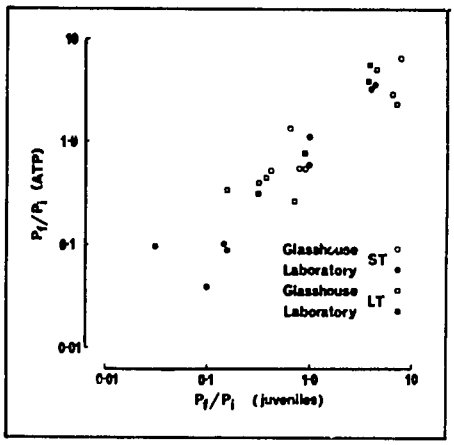

Figure 1. Comparative estimates of mean PCN-multiplication rates (Pf/Pi) (n = 5) assessed by ATP and visual dilution-counting methods under different test conditions. Data points refer to both short (ST) and long (LT) host-contact periods of inoculum on test plants (5- and 12-weeks, respectively).
Pf/Pi estimates have been corrected for unhatched juveniles in retrievable standard volumes of cysts used as inocula.

Work was subsequently initiated to develop on alternative ATP assay using a Lumac Luminescence Celltester (Model 1030). This instrument is capable of providing rapid sequential ATP measurements using purified preparations of Luciferin-Luciferase, however, work with pure ATP standards resulted in the detection of inconsistencies in measurement by this instrument. Therefore, cysts obtained for comparative work on visual dilution-counting and ATP assessments of resistance for a large number of clonal accessions of potato have been retained until current problems with the Lumac Celltester can be satisfactorily resolved.

The initial tests showed clearly that hatch of inoculum from cysts can be variable and considerably less than the 100% assumed in conventional resistance testing. (Table 1). It is suggested that residual estimates of unhatched inoculum are necessary to obtain estimates of 'true' multiplication rates (Pf/Pi) and to reduce this (significant) component of the 'environmental' influence on the reproducability of partial resistance assessments (Table 1) or, indeed, in tests of pathotypes on differentiating cultivars (Kort, et al. 1977).

Unless suitably automated methods of counting nematodes are available this requirement is unlikely to be a practical proposition for large-scale testing of PCN-resistance in the potato. The ATP method may provide a satisfactory practical solution to this problem.

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Table 1. Mean hatch of G. rostochiensis (Ro1) and G. pallida (Pa3) from standard volumes of cysts (n = 5) used as inoculum in pot (glasshouse) and closed container (laboratory) tests.

Clone	Species	Test No.	Estimated % hatch of inoculum (Pi) for indicated host-contact time (weeks)			
			Glasshouse		Laboratory	
			5	12	5	12
8906 abc	Ro1	1	45.8	59.2	33.1	53.8
		2	49.2	49.5	27.0	28.1
8906 abc	Pa3	1	23.5	38.2	40.2	48.9
		2	50.6	35.3	38.3	37.3
F49/52	Ro1	1	32.7	48.8	40.5	42.6
		2	41.2	59.5	33.4	17.6
F49/52	Pa3	1	18.0	33.7	42.2	62.7
		2	39.3	33.1	41.4	48.8
Pentland Crown	Ro1	1	13.6	44.4	28.7	50.6
		2	42.9	54.7	41.9	58.2
Pentland Crown	Pa3	1	22.4	42.7	37.8	55.4
		2	45.0	39.7	49.0	54.4
Means 1/	Ro1		37.6 (2.66)	52.7 (1.90)	34.1 (2.93)	41.8 (2.39)
	Pa3		33.1 (3.02)	37.1 (2.70)	41.5 (2.41)	51.3 (1.95)
	ALL		35.4	44.9	37.8	46.5

1/ In parenthesis: factors by which the assumption of 100% hatch of inoculum under estimates true Pf/Pi viz. increases apparent resistance.

STUDIES ON POTATO REPRODUCTIVE BIOLOGY FOR TPS RESEARCH IN THE YEAR 2000

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Introduction

The success of TPS technology will depend on the production of required amounts of true seed carrying desired attributes to produce high yields of commercially acceptable tubers. For this, a complete understanding of the reproductive biology of potato is necessary to locate important components which directly or indirectly affect TPS production and performance.

Secondly, well thought out short term and long term strategies must be defined to deal with each of the components for yielding the required quality and quantity of true potato seed capable of producing high yields of tubers under specified agro-ecological environments.

Components in reproductive biology:

Flowering

Long days (Patterson, 1953) and late planting (Rothacker, 1957) are generally conducive to flowering. Most Andigena clones flower profusely but many tuberosum varieties produce only a few flowers and in several varieties no flowers are normally formed (Howard, 1978).

Methods for obtaining flowers and preventing bud abscission are grafting onto tomatoes (Carson and Howard, 1944), and growing on a brick (Thijn, 1954) or with auxin treatments (Wiersema, 1950).

No information is available on nutritional requirements, or cultural, or irrigational needs for flowering.

Types of inflorescence

Flowers occur in cymose inflorescence but may superficially resemble a simple umbel (Whitehead et al., 1953). Although such descriptive information is available, there is an absence of information on the extent of variability among the genotypes regarding size and types of inflorescences as well as inheritance of these characters. Variability of numbers of flowers on individual inflorescences and the numbers of inflorescences on a plant as well as genetics of these traits have not been

studied. Importance of such information to TPS yield is obvious.

With a view to getting some information on variability for the number of flowers per inflorescence among genotypes and an estimate of the heritability of this character, 38 genotypes were studied. The number of flowers/inflorescence varied from 6 to 26. Heritability differences and genetic advance (as percent of mean) among the genotypes, were 89.93 and 61.82 respectively (Upadhya and Sharma, unpublished). This indicated substantial additive genetic effects and that selections can be effective.

Flower:

The flower in potato has been extensively studied taxonomically. Some information is available on the variability present among cultivated potatoes in respect to anther cone size and shape as well as the size and shape of style and stigma (Salaman, 1926; Pushkarnath, 1969). Detailed studies of inheritance of these characteristics, have not yet been made. Successful TPS production will necessitate a thorough knowledge of the implications of style, stigma, and anther characteristics for pollination and berry setting, and stigma receptivity in relation to anther maturity and opening of the flower, as both are influenced by genetic and environmental factors.

In pepper and eggplant correct information about style and stigma morphology and physiology, is essential for successful hybrid seed production (Quaglotti, 1979).

Pollen:

Pollen sterility in S. tuberosum is well known. All the cultivated genotypes of S. andigena are highly pollen fertile (Howard, 1970).

In hybrid TPS production pollen sterility of female parents would be an advantage. Maximum heterosis for total tuber yield was obtained (Dayal, 1981), with S. tuberosum female parents and selected S. andigena male parents, in comparison to reciprocal or intra group matings.

Information is available for successfully storing pollen of male parental lines (Howard, 1978). Although the use of stored pollen gave a fairly good fruit set, 28-34%, (Chalyuk, 1978) fruit size and number of seed per fruit was reduced. Hybrid TPS production will depend on the pollination efficiency and the physiogenetic makeup of the female parent to produce highest berry set and seed set/berry.

Cv. Desiree was the most effective pollinator among 82 pollinators in 228 crosses (Chalyuk, 1978) judged by percentage fruit and seed set. Upadhya and Sharma (unpublished) determined efficiency of seed set/berry of 12 pollen parents with a common female parent (Table 1). Seed set is also dependent on the physiogenetic make-up of the female parent. Upadhya and Sharma (unpublished) used a common pollen parent on 12 female parents, and found wide differences exist in the average number of seed set/berry (Table 2).

Fertilization occurs within 36 hrs (Clarke, 1940) or 40-45 hrs (Williams, 1955) after pollination, depending on the environmental conditions. They apparently

Table 1. Efficiency of pollen parents in producing seed/berry when crossed to a common female parent (K-2500).

Pollen parent	Seed/berry SD[1/]
Jeevan Kufri	206 ± 20.6
CP-1406	167 ± 27.1
PS-4904	124 ± 39.3
N-1497	57 ± 21.6
SLB/Z-405 (a)	103 ± 8.1
N_2 - 82	157 ± 43.6
JF-303	88 ± 47.4
JF-7886	115 ± 56.4
JF-5106	76 ± 20.1
O-1141	226 ± 84.1
N_2 - 81	241 ± 47.2
Kufri Safed	147 ± 18.9

1/ Standard deviation from the mean.

Table 2. Efficiency of female parents in producing seeds/berry with a common male parent (CP-1406).

Female parent	Seed/berry SD[1/]
Kufri Chandramukhi	65 ± 3.1
K-2500	167 ± 27.1
Up-to-Date	112 ± 9.4
H.C. -294	294 ± 42.8
Dhankri	318 ± 45.1
Craig's Defiance	207 ± 37.9
Kufri Jyoti	117 ± 24.6
MT-10	43 ± 18.3
MT-270	245 ± 53.8
MT-429	148 ± 43.5
MT-442	275 ± 43.2
MT-77-8	79 ± 13.2

1/ SD = Standard deviation from the mean.

did not study interaction of the physiogenetic aspects of fertilization as related to environment. Such information is necessary for effective fertilization and for evolving methods for hormone/chemical treatments to improve fertilization.

Berry:

The ovary contains numerous ovules (Young, 1922; Rees-Leonard, 1935). However information is needed concerning numbers of ovules/ovary and the degree of variability among different genotypes and inheritance of such characters.

The potato fruit may contain over 300 seed (Smith, 1977). Upadhya and Sharma, (unpublished) studied 38 genotypes and the average number of seed/berry varied between 18 and 402. The correlation coefficient (r) between berry weight and seeds/berry was + 0.7323 (significant at 1% level). Heritability (broad sense) was 95.82 for average berry weight and 95.62 for seed/berry. Genetic advance (as percent of mean) was 69.53 for average berry weight and 103.76 for seed/berry.

In production of first generation hybrid tomato seed, (Barrons and Lucas, 1942) a maximum of 3 flowers per cluster minimized competition between fruits. In potato, such information is not available.

Full dormancy and full viability are developed in potato seed borne in berries six weeks old or more; immaturity diminishes viability and, to some extent, also diminishes dormancy (Simmonds, 1963). Solanum ochranthum, demands a much longer period of maturity (observation by Beckett, quoted by Simmonds, 1963). The appropriate age for harvesting berries for maximum viability and vigor of TPS should be determined.

Seed:

Generally a positive correlation exists between seed weight and rate of shoot and root growth, at least within species (Baker, 1972).

Dayal (1981) studied 90 F_1 and selfed seed progenes to determine the correlation between 1000 seed weight and other morphological characters of the seedlings as well as the tuber yield/plant. Significant and positive phenotypic (+ 0.4131), genotypic (+ 0.4510) and non-significant environmental (+ 0.1240) correlation values were obtained between tuber yield/plant and 1000 TPS weight. Similarly positive and highly significant phenotypic (+ 0.3068) and genotypic (0.3628) with non-significant environmental values of correlation were obtained between the number of tubers/plant and 1000 TPS weight. For average tuber weight and 1000 TPS weight the phenotypic, genotypic and environmental correlations were positive but values were low and non-significant.

The 1000 TPS weight estimations of over 320 F_1 and self seed samples of tuberosum and andigena genotypes, made by Upadhya and Sharma (unpublished) showed a large variation among genotypes varying from 387 mg to 1420 mg. Heritability (broad sense) and genetic advance (% of mean) estimations gave values of 87.7 and 156.0, respectively.

Since 1000 TPS weight has shown high heritability and positive association with yield and other important characters, it would be easier to select such hybrids for producing high tuber yields.

In a comprehensive study of morphoanatomical characteristics of true potato seed, Upadhya et al. (1981) have described five types of seed based on the embryo structure. These five types (Figure 1) are designated as A to E types. Type A has true cercinnate embryo characteristic of the sub-family Solanoidae and E type shows embryos that aborted prematurely. Types B to D are fully developed embryos ranging in shape from an inverted "U" in type B to slightly bent embryos to straight in type D.

Preliminary data on synchrony and percentage germination of type A and type B embryos from 10 genotypes indicate that type A embryos are better than B type. Furthermore, seedlings from type A embryos are more vigorous (Table 3) and have higher fresh and dry weights than seedlings from other embryo types (Upadhya and Sharma, unpublished).

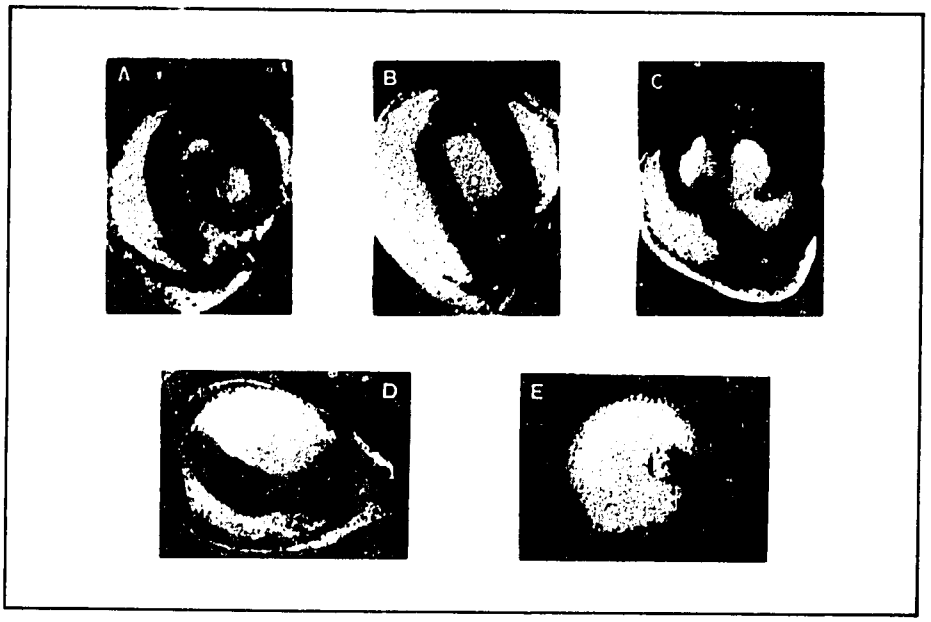

Figure 1. Five embryo types of seed found in tuber-bearing Solanum species: A, circinnate wild embryo-type A; B, inverted "U" shaped embryo type B; C, embryo type with curved cotyledons in opposit directions; D, straight embryo; and E, aborted embryo.

Table 3. Average shoot and root length of seedlings raised from A, B and C type F_1 embryos.

Embryo type	Shoot lenght cm	Root length cm
A type embryo	3.98	3.71
B " "	3.25	2.71
C " "	3.09	2.06
Standard error of mean	±0.053	±0.126
P = 0.01	0.195	0.467

Hybrid, K-2500 x CP-1406, seed 21 days after sowing, averages of 40 seedlings per type.

Embryo type seed were classified in some non-tuber bearing and tuber bearing Solanum species. (Table 4). The non-tuber bearing species produced over 90% A type seed whereas various proportions of these types were present in the tuber-bearing species.

The proportion of different embryo types for a genotype is genetically controlled. True seed of cv. Kufri Jyoti (Upadhya et al., 1981) collected from the same location for four years, from three locations between 5000-8000 ft, as well as from individual berries from one plant, were examined for the frequency of embryo types (Table 5). Variation was of the same magnitude between berries from a plant, between the three locations, and between years.

Seed, extracted from mature-green berries soon after harvest; and after 10 days and 20 days of storage at room temperature (Table 6) were consistent once the berry was mature. Proportionality of different embryo seed types did not change during the ripening.

Crosses made between genotypes showing the presence of a high proportion of type A seeds and those with low type A and high

Table 4. Percentages of seed in different embryo type distribution in some Solanum species.

Solanum species/ accession	A %	B %	C %	D %	E %
nigrum[1/]	99.8	0	0	0	0.2
xanthocarpum[1/]	99.8	0	0.2	0	0
pseudo-capsicum[1/]	99.7	0	0	0	0.3
pennellii[1/]	90.5	6.1	0	0	3.4
stenotomun					
OCH-3571	89.3	8.2	0	0	2.5
OCH-5316	57.8	41.6	0	0	0.6
goniocalyx					
CIP-700042	55.9	39.5	3.0	0	1.6
CIP-703117	57.6	40.0	0.15	0.15	2.1
chacoense					
SS-277-5	92.2	6.9	0	0	0.9
Wild	92.9	3.2	1.0	0.2	2.7
andigena					
participa-cion	61.9	37.3	0.1	0.1	0.6
renacimien-to	76.6	21.1	1.5	0.5	0.3
CUP-199	86.8	11.3	0.5	0	1.4
tuberosum					
Kufri Jyoti	12.0	69.5	9.4	I.5	7.6
Kufri Kundan	54.9	38.8	4.4	0.7	1.2

[1/] Except for these Solanum spp. all are tuber bearing.

type B showed partial dominance of type A in certain combinations and in others complete dominance (Table 7).

Seed size affected proportionality of different embryo types within a genotype, from an F_1 and open-pollinated seed lots (Table 8). There was no relationship between 1000 seed weight classes of different genotypes and proportionality of different seed types, (Table 9). This

Table 5. Variation for the embryo types in S. tuberosum, Kufri Jyoti.

Embryo type	Sample (mean ± SE percentage)		
	Within berries SE[1/]	Within years SE	Within locations in same year SE
A	15.9 ± 4.8	13.1 ± 1.4	14.5 ± 1.5
B	63.0 ± 5.4	68.1 ± 2.7	62.3 ± 2.2
C	9.4 ± 1.7	10.9 ± 2.1	11.9 ± 2.2
D	2.8 ± 0.6	1.5 ± 0.6	4.4 ± 1.4
E	8.9 ± 1.6	6.4 ± 1.8	7.0 ± 1.1

SE = Standard error of the mean.

Table 6. Effect of fruit storage before seed extraction on frequency of different embryo type seeds.

Time of seed extraction[1/]	Embryo type %			
	A	B	C	others
Soon after harvest	12.7	71.3	7.4	8.6
After 10 days	16.2	72.5	5.1	6.2
After 20 days	14.4	74.5	8.8	2.3

[1/] Mature green fruit of progeny EB/A-188 stored at room temperature.

Table 7. Segregation for different embryo types.

Parentage	Embryo type			
	A %	B %	C %	others %
Kufri Jyoti (self)	15.9	63.0	9.4	11.7
C.P. 1406 (self)	73.9	17.9	2.8	5.4
Kufri Safed (self)	75.9	22.6	1.0	0.5
Kufri Naveen (self)	65.3	30.0	4.2	0.5
Jyoti x CP-1406	30.5	62.0	4.4	3.1
Jyoti x Safed	50.3	31.0	3.3	19.3
Jyoti x Naveen	59.3	25.6	7.4	7.7
Kufri Jeevan (self)	27.8	62.1	0.7	9.4
Jeevan x CP-1406	24.9	70.3	4.4	0.4
Jeevan x Safed	23.9	71.0	3.1	2.0
Jeevan x Naveen	35.0	58.6	5.7	0.7
JEX/B-687 (self)	49.4	45.5	4.1	1.0
JEX/B-687 x CP-1406	66.3	30.0	2.7	1.0
JEX/B-687 x Safed	79.0	16.4	0.6	4.0
JEX/B-687 x Naveen	70.0	29.0	0.4	0.6

implies that the general size of the seed for a genotype is independently controlled genetically from the embryo structure.

The above observations suggest there may have been a progressive accumulation of deleterious genes in potato which affect embryo development specifically. Centuries of vegetative propagation may have allowed an accumulation of these deleterious genes in varying proportions in different genotypes. As such, true potato seed may have partially lost the potential to give rise to sturdy seedling populations capable of survival under natural conditions. Such an interpretation is supported by the fact that seed of non-

Table 8. Variation for embryo type in large (> 1 MM) medium (< 1 mm - 0.85 mm) and small seed in two progenies (<0.85 MM).

Embryo type	CUP-199 x bulk pollen F_1		
	large	medium	small
A	74.6	54.4	29.1
B	23.6	43.8	59.2
C	0.6	0.9	4.9
D	0	0	0
E	1.2	0.9	6.8
Embryo type	CIP-702267 (OP)		
	large	medium	small
A	45.7	30.0	23.2
B	50.7	60.4	35.8
C	1.3	4.4	7.8
D	0.3	0	0
E	2.0	5.2	33.2

Table 9. Percentages of different embryo type seeds among different genotypes varying in their 1000 seed weight.

Genotype (selfed seeds) 100 seed wt (mg ± SD)	Embryo type			
	A	B	C	Rest
Kufri Jyoti 524 ± 3.6	15.9	63.0	9.4	11.7
JEX/B-687 542 ± 6.9	49.4	45.5	4.1	1.0
Kufri Jeevan 429 ± 4.4	27.8	62.1	0.7	9.4
CP-1406 387 ± 4.7	73.9	17.9	2.8	5.4
Kufri Sindhuri 352 ± 5.0	43.0	39.8	4.2	13.0

tuber bearing species which propagate through true seeds always show only type A embryos (Table 5). Therefore, it seems obvious that selection for highest percentage of type A seed in cultivated potatoes has to be made for the seed to regain their potential vigor and ecological superiority.

Conclusion

Six important components exist in the reproductive biology of potato, on which only a limited amount of information is available for achieving the required status of TPS and for the demands of the year 2000.

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THE POTATO FOR THE HOT HUMID TROPICS

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Introduction

The primary focus in agricultural research and development, in the tropics, is towards increasing the production of food of high quality. Approximately two billion people, constituting nearly a half of the world's population inhabit this region. All forecasts agree that this figure will increase rapidly in the next few decades. And, the production of the principal source of food; wheat, rice, and corn, has fallen far short of the requirements to stave off hunger and malnutrition. Ironically, this is despite the benefits that have accrued from the green revolution and other technological advances, to maximize productivity.

Production of a diversity of other food crops, primarily root and tuber crops, estimated at 40% of the food grain supply, has been able to supplement this short fall in grain production. Yet, present statistics reveal that, in the tropics, 15 million children die annually of malnutrition and other related diseases.

These facts suggest, therefore, that the conventional sources of food in the tropics have started to reach the limits of their productivity. Consequently, it is fundamental to search for other sources of food and the potato ha now become the focus of attention in many tropical countries. Two principal factors have contributed to this predisposition towards the potato.

1. The potato is one of the most efficient crops; it is now accepted to be superior to every other food crop in its ability to produce food per unit area per unit of time.

2. It is one of the World's most nutritious sources of food; the ratio of protein to carbohydrate is far greater in potatoes than in many of the cereals and other root and tuber crops.

These qualities, par excellence, in the potato, can, therefore, contribute to the challenges that confront many tropical countries to ward off hunger and malnutrition. Traditional agricultural experts may have reservations, and, perhaps scoff at this suggestion. But right thinking social scientist and agriculturists will agree that these old notions are not based on facts. Take the classic example of wheat - a traditional temperate crop but is now widely used as source of food in most tropical countries where many millions of tons are traded, annually.

What of the potato? Here is a crop that had its origins in the tropical highlands of Peru, but now considered as a temperate crop merely because it was bred, developed and improved in the environs of Europe and N. America and Oceania. Even so, the potato was introduced into several tropical countries by the Europeans subsequent to their domination. It is nevertheless a sad commentary in the history of agricultural development that no attempt was made to develop this crop in the natural environment of these countries with the prospect of broadbasing the areas of production. Instead, the technology developed in the temperate countries was translated into the cool highlands of the tropics. This seemingly simple development of the potato in the tropical highlands engendered high cost of production. Consequently, potatoes are available only to the elite few, and even today it is a minor vegetable crop in the tropics.

Of course, all this is a part of history. What is the future of the potato in the tropics?

Potentials for production

Statistics obtained from several tropical countries reveal that in spite of the many socio-economic constraints potato production has been increasing steadily. Nonetheless, the fundamental objective in developing the potato, in the tropics, is directed towards exploiting the qualities of its excellence to combat hunger and malnutrition. The potentialities for attaining these objectives devolves, among other things, on two basic factors.

1. Increasing productivity
2. Reducing the cost of production.

1. Increasing productivity. At the present time, potato production in the tropics is confined primarily to the highlands. Due to steep terrain and other ecological considerations, the potentialities for substantially increasing the land area for potato production are relatively small. Additionally, the expected contribution to total production by increasing the yield is marginal.

How can we then increase potato production substantially in the tropics? The only prospect of increasing the land area significantly is by exploiting the extensive land resources in the low-lands. This will in effect mean that the potato must be taken "downhill".

The first recorded evidence of taking the potato downhill was in Sri Lanka (Caesar, 1967). The results of the research carried out in the late 1960's have now been translated into farmers fields. At present potatoes are produced in 600 ha, at sea level annually in the northern part of Sri Lanka. The on-farm yields ranging between 16-25 ton/ha are obtained from potato cultivars developed in temperate regions.

The production of potatoes, at sea level, was achieved by judiciously synchronizing the time of planting with the relatively "cool" night temperatures that prevail during a specific period during the year (Panabokke, 1980). During the period of growth and development the maximum temperatures ranged between 29 - 32°C and the minimum temperatures between 19 - 22°C. These minimum temperatures are 5 - 10°C higher than in the traditionally potato growing areas of the country. Even so, it was found that the same cultivars produced the highest potential yields in climatically diverse locations. This suggests that some cultivars have a high degree of genetic plasticity to temperatures (Weerasinghe, 1980). Recent advances in potato research in Sri Lanka have identified several other locations at sea level where potatoes can be successfully grown.

Scientists at CIP adopted a different strategy for taking the potato downhill. They cooled the mirco-environment by adapting varied agronomic practices. A mulch or a soil reflectant was used to keep the soil temperatures from rising rapidly while retaining the moisture at optimum levels while the plants were fully exposed to the sun. Alternatively they utilized a temporary shade until the plant canopy developed fully. Or, by intercropping with coconut, thus, providing a permanent shade during the growth and development of the potato.

Thus, by closely monitoring the time course changes in the maximum and minimum temperatures and/or by the use of varied agronomic practices, the potential for expanding potato production in the lowland tropics has been demonstrated. Nevertheless, application of these principles in the production of potatoes at these lower elevations will be dependent on several interacting social and economic factors.

These advances, in potato research, have no doubt opened new vistas in production in the lowland tropics which are hot and humid. However, the greatest challenge to potato production in these areas will be contingent on the development of heat tolerant strains that will permit potato production throughout the year without having to depend on the finer points of agrometerology and agronomy. If this can be achieved by the year 2000 then the projected objectives of substantially increasing the land area for potato production can be a reality.

2. Reducing the cost of production. The primary objective in increasing productivity of potatoes is to make this highly nutritious source of food available to a greater majority of the people in the tropics whose incomes are low. However, the high cost of production is the major constraint in achieving this goal. For, potato production is intimately dependent on conventional methods, use of disease free, clean 'seed' tubers, which are either imported from commercial seed growers and/or supplemented by local production in the cool highlands of the tropics. Estimates reveal that, in the tropics, 50-60% of the cost of production is expended on seed tubers. Transportation costs from distant points to the centers of production and the products to the consumers eventually require premium prices for potatoes.

The scientists in the People's Republic of China were the first to take a pragmatic approach to reduce the production cost of potatoes by adapting the use of botanical or true potato seed (TPS) for the commercial production of potatoes.

This being so, research in TPS technology is now receiving the concerted attention of several scientists, the world over. The advances so far made are encouraging. Nevertheless, the challenges are many and varied. Ideally, what is expected is the development of true potato seed which can produce robust seedlings with early vigor, with resistance and/or tolerance to the wide array of pests and diseases and adapted to the hot humid tropical environment so that potatoes can be produced at any time of the year. If this can be achieved in the next two decades it will revolutionize agriculture in the tropics, and will provide a highly nutritious source of food at low cost, thereby, subscribing to the attempts made at eliminating hunger and malnutrition in the tropics.

This short article has attempted to focus attention on the prospects that exist for producing potatoes in the hot humid tropics. The recent advances in research have openend new vistas for the development of the potato in the centers of high population pressure with the expectation that this highly nutritious source of food will be available to a greater majority of the people whose incomes are low. If these aims can be achieved during the next few decades it could well represent a significant revolution in agriculture.

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MANAGING NEMATODES AND SOIL-BORNE POTATO DISEASES IN A SUBTROPICAL PRODUCTION SYSTEM

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Summary

We discuss management of nematodes and soil-borne diseases in a complex subtropical pathosystem. The system includes several plant parasitic nematodes, bacterial wilt, corky ringspot disease, early dying and tuber scurf. Different control strategies consistent with the potato production system are dictated by the pathogens present, market destination of the crop and soil moisture at the time of planting.

Introduction

Approximately 8-9000 ha of potatoes are grown in Northeastern Florida (NEF) in a zone 8-16 km wide and 50 km long along the St. Johns river. The sandy flatwoods soils average <2% both in organic matter and clay content. Fields are sublayered at 35-150 cm by an impervious layer of clay and have poor internal drainage. The clay layer facilitates use of seepage irrigation through a series of water furrows running at 18.3 m intervals lengthwise through fields. Following heavy rains fields are drained through the same furrows and aided by cuts made across rows in low areas of fields. The crop is grown on ridged rows having apices of ca 35 cm and spaced on 102 cm centers. The crop is planted in December-February and harvested during April-June. Traditionally 80-90% of the crop has been sold to potato chip processors, largely through preseason contracts. However, due to more favorable prices in the fresh market during the past 2-3 years, the proportion being sold as table ware has increased to nearly 40% of the total NEF production. A summer cover crop of sorghum (Sorghum vulgare x Sudan grass hybrid) or volunteer cockleburr

(Xanthium pennsylvanicum) is usually grown. Most fields have been annually cropped to potatoes and a summer cover crop for >70 years.

The System

In order to place the management system for soil-borne diseases in NEF into perspective, it is necessary to present some detail. A complex pathosystem involving 13 genera of plant parasitic nematodes and several bacterial, fungal, and viral pathogens must be dealt with. Belonolaimus longicaudatus (BL) and Meloidogyne incognita (MI) are the most important nematodes affecting potato yields whereas trichodorids (TR) are important as vectors of corky ringspot (CRS = spraing) disease. Diseases associated with nematodes in NFF include bacterial wilt, (BW) Pseudomonas solanacearum); early dying, (ED) Verticillium albo-atrum; Rhizoctonia tuber scurf and CRS. (Weingartner et al., 1982). Resistance or effective chemical control procedures have been identified for most of these problems. Unfortunately, not all NEF potato fields have the same soil-borne pathogens and in many instances multiple problems exist (eg. BL+TR+CRS, BL+MI+BW, etc.). A second complication is that although resistance to CRS and tolerance to BW are known, only one cultivar (Green Mountain) has been identified which has a level of resistance to both. Even the effective chemicals complicate our scenario because the materials available to growers vary in their effectiveness both due to the pests and according to soil moisture and temperature conditions at the time of application. For example, soil fumigants are most effective when soil moisture <12-15%, are phytotoxic and must be applied several weeks before planting, reduce incidence of BW, and fail to control CRS; whereas nonvolatile nematicides such as aldicarb are most effective when soil moisture >12-15%, can be applied at or after planting, control CRS, but fail to reduce incidence of BW. The last complication is whether the crop is destined for potato chip processing or the fresh market. Not all potato cultivars are suitable for potato chip processing because they possess insufficient solids or excessive reducing sugar content. Green Mountain, for example, although possessing a degree of resistance to both BW and CRS produces dark undesirable potato chips. Similarly, certain external tuber quality defects are acceptible for processing potatoes, but not for those destined for the fresh market.

A management concept for controlling these problems has been developed for NEF. All available control options, chemicals, disease resistance and a combination of these, have been assembled into a two dimensional matrix or grid. Depending upon market destination of the crop, soil moisture at time of treatment and diseases present, various control options are listed. The options include all of those which are known even though some are not practicable to growers due to unavailability of seed, prohibitive costs of chemicals, etc. The matrix, therefore, also provides a ready summary of available control procedures to help guide future research.

Research into the next two decades should emphasize strengthening the weaker components of the management system. Variety improvement is needed. Cultivars with desirable horticultural characteristics for NEF and which have resistance to BW, CRS and MI are needed. Information is lacking on effects of different summer cover crops, multiple cropping sequences and crop rotations on nematode population dynamics and incidence of soil-borne diseases. More data are needed on interactions and competition among nematode genera and other soil-borne pathogens as this information may have importance in biological control methods. Lastly, we know little concerning economic thresholds of the various pathogens and even less concerning adequate sampling procedures. This information is vital to any total management system involving soil-borne diseases.

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CONTROLLING CORKY RINGSPOT DISEASE (SPRAING) IN FLORIDA

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Summary

We present data leading to a series of questions concerning population dynamics and interactions among ectoparasitic nematodes. Some of our comments tend to be speculative. However, since our intent is to suggest research for the next two decades which may contribute to our knowledge of nematode population dynamics and could lead to new biological control methods, some speculation is warranted.

Introduction

Soil fumigation reduces the incidence of spraing (corky ringspot disease (CRS)) in most potato production areas of the world where the disease occurs. Soil fumigation, however, not only fails to control CRS in northeast Florida (NEF), but can result in significant increases in the disease (Table 1) (Weingartner, et al. 1982). Although standard fumigation procedures in NEF kill the trichodorid vectors in the planting zone (10 cm deep) lethal concentrations of fumigants fail to penetrate deeper than 30 cm. Trichodorids (TR) migrate from the deeper soil into the fumigated zone within 35-45 days after the crop is planted and transmit the virus.

Table 1. Percent tubers with spraing in selected chemical control experiments at Hastings, Florida.

Nematicide	Season[1/]		
	1977	1978	1981
1,3D	17.6c	57.6c	43.0c
Aldicarb	6.4a	2.4a	3.8a
Nontreated	10.8b	28.5b	20.8b

[1/] Values within a column followed by the same letter do not vary significantly. (P=.05)

The population dynamics of TR in Florida soils have been recognized to be unique since the 1950's. Christie and Perry (1959) reported that in some Florida crops population densities of TR increased to levels several times those in nontreated soil. Large increases in population densities of TR do not occur in potato because the nematodes do not multiply effectively on this host (Harrison, 1976). Data are presented which support the hypothesis that increases in spraing observed in NEF potatoes and in population densities of TR in other Florida crops are due to reduced competition with Belonolaimus longicaudatus (BL), another important ectoparasitic nematode indigenous to sandy soils of Florida.

Results and discussion

Competition of BL and TR for feeding sites might be anticipated because both feed near root tips and the response of susceptible hosts to their feeding is similar (Christie 1959). We observed in 1977 that mid-late season population densities of TR in a CRS control experiment illustrated a significant negative correlation with those of BL (Table 2). A review of fumigation data (Christie and Perry 1959) revealed a similar relationship. Densities of TR and BL tended to be inversely related (Table 3), with population densities of one tending to be low when those of the other were high. Subsequent communication with other Florida researchers who observed resurgence of TR populations in their experiments following fumigation indicated that in each case BL was also present in the test area.

Although moderate increases in population densities of TR due to migration of the nematodes are observed following fumi-

Table 2. Correlation coefficients of B. longicaudatus x trichorid population densities in a 1977 experiment.

Belonolaimus longicaudatus	Trichorids [1/]		
	April 7	May 2	May 5
April 7	-.29xx	-.38xxx	-.25x
May 2	-.26x	-.13x	NS
May 5	-.23x	NS	NS

[1/] /xxxP => .001; xxP = .002-01; xP = 02-.10

Table 3. Population densities of B. longicaudatus (BL) and trichodorids (TR) in a 1958 experiment (Christie and Perry, 1959).

Days after fumigation	Nematodes/100 cm^3 soil			
	Nontreated		Treated	
	BL	TR	BL	TR
30	36	9	5	5
60	94	29	1	64
90	66	21	4	146
180	46	24	1	110

gation of potato crops in NEF, (Weingartner, et al. 1982) the dramatic resurgence reported elsewhere does not occur (Table 4). It seemed possible that the increase in CRS following fumigation might be an expression of increased feeding by the vectors and that resurgence might be observed if a good host for both TR and BL were planted in a potato field. Cabbage and potato were planted in fumigated and nonfumigated soil and population dynamics of TR and BL observed. Population densities of TR in the cabbage crop were three times greater in fumigated soil than in nonfumigated soil (Table 5). In addition, a striking inverse relationship between TR and BL was observed. Resurgence failed to occur in potato, however, the inverse relationship between BL and TR was observed in this crop as well.

It is apparent that TR failed to resurge in potato fields simply because potato is a poor host for the nematodes. Our observations lead to several interesting questions to be studied into the next decade:

1) Do TR and BL compete for feeding sites on roots?
2) If competition between BL and TR is demonstrated, can it be used through manipulation of differential hosts, and other means, to control CRS and ectoparasitic nematodes?
3) Is the increase in CRS following fumigation due to increased feeding by TR as a result of reductions in population densities of BL?
4) Do other ectoparasitic nematodes which feed near root tips behave similarly?
5) Will previous feeding by one ectoparasite inhibit feeding by another?

Table 4. Typical population dynamics of trichodorids following fumigation of NEF potato soils (1977).

Nematicide	Trichodorids/100 cm^3 soil[1/]			
	11 Feb.	7 April	2 May	23 May
1,3D	1c	15a	14a	27a
Aldicarb	9a	5b	4b	6b
Control	6a	6b	3b	6b

[1/] Values followed by the same letter do not vary significantly (P=.05)

Table 5. Belonolaimus (BL) and trichodorid (TR) population densities on a host (cabbage) and non host (potato) crop following soil fumigation, 1979.

Plant and treatment	Nematodes/100 cm^3 soil			
	15 April		30 May	
	TR	BL	TR	BL
Potato				
1,3D	29	26	65	62
Control	18	184	36	119
Cabbage				
1,3D	220	8	152	33
Control	72	620	18	105

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POTATO SEED-TUBER PRODUCTION FROM TRUE SEED

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Introduction

Use of true potato seed (TPS) can considerably reduce the cost of healthy planting material. Until recently, potato production from TPS was based on transplanting seedlings from nursery beds or direct seed sowing in the field. Plant establishment and early vigor with these methods can present problems, especially under field stress conditions. To overcome these problems, this study was initiated to explore the possibilities of producing seed tubers from TPS and using such tubers for planting according to the conventional way.

This paper describes experiments in Peru during 1981.

Materials and methods

TPS was sown in 1 m wide ground beds filled to a depth of 25 cm with a 1:1 mix of peat moss and sand. Seedlings were thinned several times during the first 20 days after emergence. Plants were "hilled" by adding a 5 cm layer of mix to the beds. NPK fertilizer was applied to the mix before sowing at a rate of 18-18-18 g/m^2, while the top 3 cm of the mix received another 0.1-0.3-0.1 g NPK/kg of mix at sowing. Additional fertilizer was applied in the irrigation water at a rate of 3-3-3 g NPK/m^2. Number of these additional fertilizer applications varied from 3-6 per experiment, depending on foliage development. Shade, resulting in a light reduction of 50% was applied to the ground beds for 2 weeks after emergence.

Seedling populations used in density experiments were 50, 100 and 275 seedlings per m^2 after thinning. Plants were distributed in a square pattern at plant spacings of 14 x 14 cm, 10 x 10 cm and 6 x 6 cm.

Tubers were harvested 120 days after sowing, stored for 4 months in natural diffused light at ambient temperature and planted in the field for multiplication at CIP experimental station in Lima, Peru.

Results and discussion

Increasing seedling populations had a positive effect on total number of tubers, mainly due to the increase of tubers smaller than 10 g (Table 1). Percentage of surviving plants decreased considerably

Table 1. Effect of plant population on seed tuber production in direct seeded nursery beds. Progeny: DTO-33 op.

Plants/ m^2 (Surviving plants %)	Number of tubers per m^2					Yield [1/]
	<1g	1-10g	10-40g	>40g	>1g	
50 (64)	74	219	119	16	354	4.5
100 (41)	133	261	134	17	412	4.8
275 (17)	375	467	153	10	630	5.9
LSD 0.01	80	64	ns	ns	128	1.5
LSD 0.05	53	42	ns	ns	85	1.0

[1/] Total tuber yield (kg/m^2).

as the seedling population increased because of competition between plants. Because of this competition, less vigorous seedlings, which may represent less desirable genotypes, are likely to have been eliminated. This process has possibly a positive effect on uniformity and yielding capacity of progeny tubers. For production of a high number of tubers per unit area, seedling populations should be at least 100 plants per m^2 after thinning. Optimum plant population is likely to be progeny specific since tuber number per plant is genetically controlled.

Hilling increased total tuber number significantly but did not affect total yield (Figure 1). Hilling, consequently, resulted in smaller tubers. Elimination of hilling can increase tuber size and has the added advantage of eliminating one field operation and hence lowering production costs.

During field multiplication of 3 tuber grades smaller than 20 g (Figure 2) planted at the same planting rate, seed-tuber size did not significantly influence total tuber yield, despite observed lower vigor of plants from the smaller tubers. The number of main stems per unit area, however increased as seed tuber weight decreased. It, thus, seems that lower plant vigor of the smaller tubers was compensated by higher stem number per unit area. The low planting rate resulted in a high weight multiplication rate for seed size tubers (20-55 mm) ranging from 25-32.

Thus, a large number of seed tubers from TPS can be produced per unit nursery area. These tubers can either be planted directly for ware potato production or further multiplied in areas where environmental conditions permit production of healthy tubers. Seed tuber multiplication seems attractive because of the high multiplication rate from planting small tubers. Furthermore, when tubers are multiplied in the field, the nursery space can be substantially reduced. Without field multiplication about 100 m^2 nursery space is required to produce seed tubers for 1 ha of ware potatoes. One field multiplication of seed tubers can reduce nursery space to 30 m^2 for the same amount of seed tubers, while 2 field multiplications can reduce the space to 3 m^2.

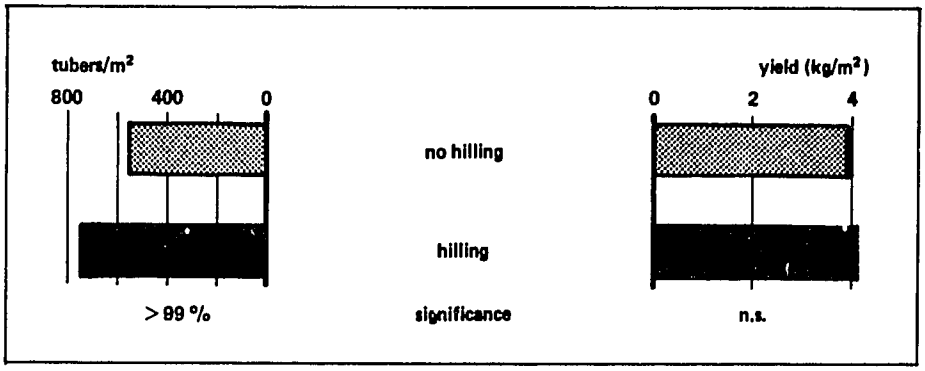

Figure 1. Effect of hilling on seed tuber production in directly sown TPS nursery beds (DTO 33 op.).

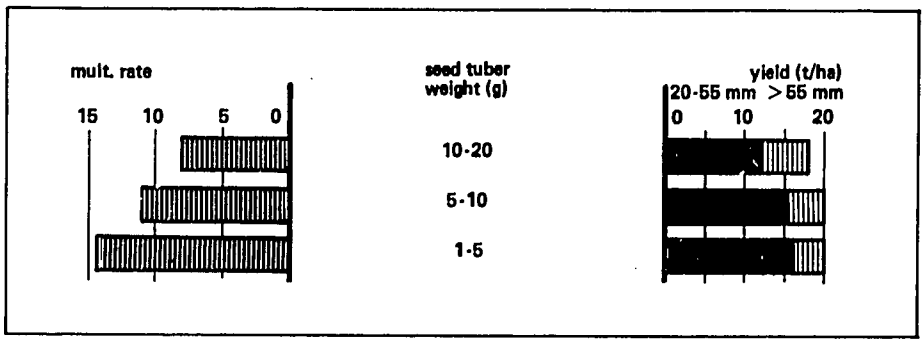

Figure 2. Field performance of three grades of seed tubers produced from TPS (DTO 33 op., planting rate 0.5 t/ha).

Production of seed tubers from TPS in proximity of ware potato production areas can overcome problems related to transport of seed tubers from distant areas. Prolonged seed tuber storage may be avoided when seed tubers from TPS are produced during off-season periods. This should be possible in many growing areas since growing conditions are relatively easy to control in a small nursery area.

Tuber size may be rather small when seed tubers produced in nursery beds are directly planted for ware production. Use of small tubers by growers in tropical environments has frequently been discouraged since small tubers are often associated with high disease incidence. On the certified seed tuber market, however, small tubers are valued higher than large tubers because of their high sprout number per unit weight, resulting in lower planting rate per unit field area (Van der Zaag, 1973). Furthermore, growers in many tropical areas are used to field practices related to the use of small tubers.

It may be concluded that the system of seed tuber production from TPS can provide potato growers in developing countries with a simple, promising method of producing healthy seed tubers in their own environment.

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THE INFLUENCE OF PRODUCTION AND STORAGE CONDITIONS ON SEED TUBER PERFORMANCE IN WARM CLIMATES

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Introduction

Availability of varieties adapted to warm climates results in an increasing demand for seed tubers in those areas. Traditionally, seed tubers for these climates are produced in cool highland areas and in subsequent generations grown at lower altitudes. In order to reduce seed tuber costs there is an increasing interest in production and storage of seed tubers at lower altitudes at higher temperatures. Several researchers have reported on the effect of seed tuber production site and storage conditions on subsequent growth and yield (Went, 1959; McCown and Kass, 1977; Carls and Caesar, 1979; Wurr, 1979).

Quantification of these effects under tropical conditions would answer the question if seed tuber production at lower altitudes would be viable as far as physiological seed tuber quality is concerned. This paper summarizes results of trials in Peru from 1979 to 1981.

Materials and methods

1979/80 experiments. Healthy seed tubers of the variety Désirée were grown simultaneously at 3 locations (Table 1), harvested at approximately the same time and stored for 6 months either at 12°C or in a commercial cold store set at 4°C. Tubers from the 3 growing sites and the 2 storage conditions were then planted in Lima, San Ramon, and Huancayo.

Table 1. Environmental data during growing seasons.

	Location		
	Lima	San Ramon	Huancayo
Altitude m.a.s.l.	240	800	3,280
Mean max. air temp. (°C)	26.3	28.8	20.0
Mean min. air temp. (°C)	17.8	19.3	6.7
Mean soil temp. at 10 cm (°C)	26.0	26.3	13.4
Rainfall (mm/month)	0	239	184

1980/81 experiments. The same procedure was followed as in 1979/80 experiments with the varieties Désirée and Rosita. In this experiment the 12°C dark store was replaced by storage in a natural diffused light store in the highlands with an average temperature of 12°C. At the end of the storage period, sprouting and rooting capacities were determined in a sprouting test using humid peat moss at an average temperature of about 20°C. In separate series of experiments, seed tubers harvested in Huancayo and Lima were stored at 4°C and at ambient temperature in diffused light in Lima, San Ramon and Huancayo, respectively. Seed lots were replanted in different locations.

In all experiments, dark stored tubers were pre-sprouted at ambient temperature at the location of planting in diffused light for two weeks.

Results and discussion

Effects of seed tuber origin are summarized (Table 2). In 18 experiments over the 2-year period involving 2 varieties, 2 storage conditions and 3 planting locations, seed tubers produced in Huancayo always emerged faster producing more vigorous plants, thus giving earlier soil coverage and in 11 of these trials giving significantly higher yields. Differences in subsequent yield from Lima and San Ramon grown seed tubers were not significant, except in 1980/81 with Désirée after storage at 12°C. The faster emergence and more rapid initial foliage growth of Huancayo produced seed tubers is possibly related to the superior sprouting and rooting capacities observed in the sprouting test (Table 2). These results are in contradiction with theories of physiological age, according to which cool grown seed should be expected to show slower initial foliage growth than warm grown seed.

Tubers stored at 12°C produced more foliage weight in the sprouting test (Table 2), but the effect of storage conditions on tuber yield (Tables 2 and 3) was generally small and no significant differences were found in 19 out of 23 trials. In the 4 trials where cold stored seed yielded significantly more, the tubers originated from San Ramon. This suggests that San Ramon produced seed tubers may be more sensitive to storage conditions. The reasons for this may possibly be associated with field conditions immediately prior to and during harvesting and are under further investigation.

Table 2. Effect of seed tuber origin and storage condition[1/] on rooting-sprouting capacity and subsequent yield of two varieties.

Characteristic variety, year	Seed tuber origin			
	Lima	San Ramón	Huancayo	Average
Dry root weight				
Désirée 79-80				
4°C	62	96	176	111
12°C, DS	68	95	156	106
Désirée 80-81				
4°C	51	89	132	91
12°C, DL	63	78	101	81
Rosita 80-81				
4°C	91	70	128	96
12°C, DL	104	97	190	130
Average	73	88	147	
Dry foliage weight (g/seed tuber)				
Désirée 80-81				
4°C	0.74	0.64	2.30	1.23
12°C, DL	1.52	0.98	2.96	1.82
Rosita 80-81				
4°C	1.32	1.36	2.28	1.65
12°C, DL	2.14	2.02	2.76	2.31
Average	1.43	1.25	2.58	
Subsequent yield[2/] (t/ha)				
Désirée 79-80				
4°C	18.0	18.4	24	20.1
12°C, DS	19.5	17.6	23.2	20.1
Désirée 80-81				
4°C	26.5	28.0	34.5	29.7
12°C, DL	25.0	14.2	32.4	23.9
Rosita 80-81				
4°C	27.7	26.0	27.7	27.1
12°C, DL	23.2	21.4	30.2	24.9
Average	23.3	20.9	28.7	

1/ 4°C: Commercial cold store; 12°C, DS: Dark store; 12°C, DL: Diffused light store at ambient temperature.

2/ Mean yield of 3 planting locations.

Table 3. Effect of storage conditions on yield of seed tubers from two locations (cv. Revolución).

Seed tuber origin	Location of replanting	Storage conditions[1/]	
		4°C	D.L.
Huancayo	Huancayo	15.7	20.2
	Lima	30.9	33.8
	San Ramón	33.1	30.9
	Average	26.6	28.3
Lima	Lima	26.8	27.4
	San Ramón	28.8	27.9
	Average	27.8	27.7

1/ 4°C: Commercial cold store.
D.L.: Ambient temperature diffused light store, at replanting location.

Results to date suggest that seed tubers from highland areas had a relatively high and stable production capacity, which is little influenced by storage conditions. Seed tubers from lower areas grown at higher temperatures on the other hand showed lower and more variable production capacities, which may occasionally also be influenced by storage conditions. This would make the use of seed tubers from cool areas less risky than use of seed tubers from warmer areas.

Although seed tubers produced in cool regions were physiologically superior to those produced in warmer regions, this does not necessarily rule out the use of the latter under certain conditions. For example, highland seed may not be available at the required time for planting in warmer areas. In those cases, higher economic yields due to early or late harvesting may be obtained by planting warm produced seed in the right physiological condition before or after well sprouted cool grown seed becomes available.

Also in certain situations, for example where warm growing areas are distant from cool growing areas, the high cost of transporting the cool produced seed may not economically justify its use. Similarly, careful attention needs to be paid to the most appropriate and most effective seed storage system according to specific local needs and conditions. The results of these trials indicate that low cost natural diffused light stores can in some circumstances make available seed of similar physiological quality as that stored in commercial cold stores.

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THE EFFECT OF TEMPERATURE ON TRUE POTATO SEED GERMINATION

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Introduction

Reports on potato production from true seed have cited high temperatures as a factor causing severe reductions in seed germination and seedling growth (Bedi, Smale and Burrows, 1979; Kunkel, 1979; Accatino and Malagamba, 1982). Studies using constant temperature regimes have demonstrated that maximum germination occurs at 15 to 20°C, but drops off rapidly between 25 and 30°C (White and Sadik, in preparation). There are reports that fluctuating regimes can improve germination (Clarke and Stevenson, 1943; Lam, 1968) these raise the question of how comparable are data from constant temperature trials to situations more similar to field conditions with strong diurnal fluctuations.

Therefore, the effect of fluctuating regimes was evaluated for two cultivars. As well as to determine how modification on imbibition rate (water uptake) might explain some aspects of the germination response under fluctuating conditions.

Results

Effect of fluctuating temperatures

The effect of fluctuating temperatures on germination was evaluated for non-dormant seed of DTO-33 open pollinated (op) and "Renacimiento" op. at 15°C as a base temperature and daily treatments of 0, 1, 2, 4, 8, 16 and 24 hours at 30°C, achieved by transferring materials between two incubators.

All treatments four replicates of 100 seeds each were started at 30°C, except for the 0 and 16 hour treatments which started at 15°C., sown in petri plates lined with water soaked filter paper. Germinated seeds were counted and removed daily.

Germination at the regimes used, was not improved by fluctuating temperatures. If the different treatments are expressed as equivalent average temperatures (e.g. a regime of 8 hours at 15°C and 16 hours at 30°C would be equivalent to an average of 25°C), both materials gave best germination at a constant 15°C, with germination declining as the 30°C treatment was prolonged (Figure 1).

To test whether data from constant regimes could be used to predict germination under fluctuating temperatures, data from previous constant temperature trials were used to predict expected germination assuming that the fluctuating regimes would result in the same germination as from the corresponding average temperatures. Curves for germination as predicted by this simple model are included in Figure 1. The average errors, measured as percent of absolute deviations from predicted germination of Renacimiento op., were 1 and 5 percent at 7 and 12 days, respectively, and of DTO-33 op., were 5 and 1 percent. While these errors are small enough to justify using constant temperature data to make preliminary predictions about performance under fluctuating conditions, they are not so small as to eliminate the need for a more complete understanding of the effects of other fluctuating temperature regimes on germination.

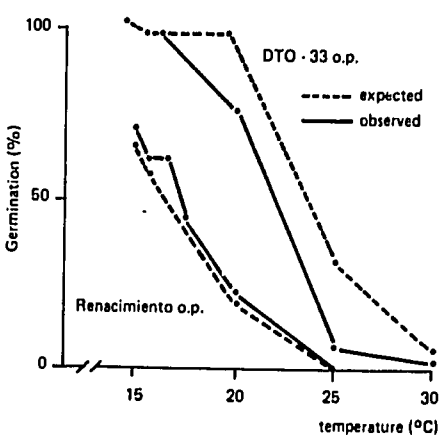

Figure 1. TPS germination under fluctuating temperatures.

Effects of temperature on seed imbibition

A simple model to explain differences between germination under constant and fluctuating conditions is that germination consists of a series of process with differing temperatures responses. Thus, depending on the stage of germination, a given temperature change might either accelerate or delay overall germination. The effect of temperature on imbibition of water by seed was determined because it is one of the most important process in germination.

Higher temperature was expected to hasten imbibition, but not to modify the plateau in water uptake which usually occurs after a phase of rapid imbibition. Early effects of fluctuating temperatures might be used to predict time required to reach the plateau level. For example, if a 30°C treatment reached the plateau in 12 hours, and 15°C in 24, one would expect that seed at a regime of 12 hours of each temperature would reach the plateau in 18 hours if started at 15°C, or 12 hours if started at 30°C.

Seed of the cultivars used above two replicates each of 100 g of non-dormant seed were imbibed with water kept at either 15 or 30°C, and placed in incubators at the corresponding temperature. At various intervals, the samples were removed individually, dried slightly on filter paper in a Buchner funnel at a vacuum of 250 mm for 60 seconds, and weighed to determine the relative moisture uptake (imbibed weight divided by initial weight).

Although seed at 30°C imbibed water more rapidly than at 15°C, plateaus reached were not as expected (Figure 2). DTO-33 seed at 30°C absorbed about 10% more water than at 15°C. With "Renacimiento" there was no clear plateau at 30°C. Rather, seed reached a peak of water absorption, and then decreased in weight. Thus, it was impossible to apply a simple model for effects of fluctuating temperatures, and suggest that the effect of temperatures on imbibition involves considerable more than a simple rate effect.

Therefore care should be exercised in performing treatments involving immersion of seed in aqueous solutions of chemicals such as gibberellic acid or calcium hypochlorite since temperature apparently can have a marked effect on the amount of solution imbibed.

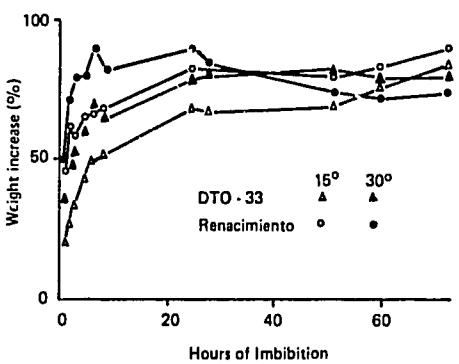

Figure 2. Imbibition rate as affected by temperature.

Conclusion

The evaluation of germination under fluctuating conditions indicated that data from constant temperature trials can serve to make qualitative prediction on germination response under field conditions. Nonetheless, there was enought difference between observed and predicted germination using constant temperatures to justify further investigation.

An attempt to interpret germination in terms of imbibition rates failed because the effect of temperature was more complex than expected. The same data serve to provide a warning that seed treatments involving immersion in aqueous solutions should be performed under defined temperature conditions because the rate of uptake is expected to be very temperature sensitive.

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PRELIMINARY STUDIES ON THE EFFECT OF TRUE POTATO SEED QUALITY ON SEED GERMINATION AND SEEDLING VIGOR

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Introduction

It is clear from a broad range of reports on potato production from true seed that one of the most critical problems is obtaining vigorous and uniform seedlings. To improve possibilities of obtaining vigorous potato seedlings under farm conditions, three areas of research are of major importance: breeding for seed vigor; development of technologies to guarantee production high quality seed; and identification of agronomic techniques needed to assure realization of the potential within the limits of farmer resources.

This paper describes studies of various aspects of seed production which indicate that it is possible to improve seed quality markedly through berry selection, berry ripening under controlled conditions, seed separation by weight, and seed treatment using chemicals.

Results

Berry selection

Berries from 3 open-pollinated clones grown in San Ramon, Peru, were harvested on a single day, described individually for characters such as surface browning, cracking, and presence of fungal growth. They were left to ripen at 20°C, and extracted individually when fully ripe (3 to 4 weeks for most berries). After treatment with 1500 ppm GA for 24 hours to break dormancy, 70 mg of seed from each berry were germinated in petri plates lined with water soaked filter paper and maintained 15°C.

Germination of seed from most berries was excellent (Table 1), even among those showing defects. However, some berries contained seed with germinations as low as 21 percent. In attempting to identify factors which explained the poor germination, the only difference noted was that the berries which gave poor seed were among those which were nearly ripe at the time of the berry harvest (as indicated by the short interval between harvest date and full ripeness). Since complete duration of berry growth and maturation was not measured, it is not possible to conclude whether apparent early ripening resulted from an acceleration of growth or ripening, or simply reflected differences in the date of fruit set. However, appropriate selection of berries for seed extraction should improve seed quality significantly.

Table 1. Germination of seed from individual berries harvested on a single date.

Clone and condition of berry at harvest	Days from harvest to full ripeness	Seed wt. (mg)	Germination at 14 days (%)
Clone 33.5			
Green	31	0.60	87
Green	30	0.53	84
Green	31	0.56	85
Nearly ripe, deep cracks	2	0.50	86
Green, crack at pedicel	18	0.57	89
Green, surface browning	30	0.61	93
Nearly ripe	2	0.50	66
Clone 35.4			
Green	29	0.61	97
Green	18	0.64	92
Green	30	0.68	96
Nearly ripe	4	0.65	36
Nearly ripe	4	0.60	21
Nearly ripe, deep cracks	2	0.69	94
Green, moderate surface damage	10	0.57	100
Clone 40.7			
Green	10	0.60	92
Green	28	0.50	96
Green	16	0.52	96
Mold, very dry	2	0.53	81
Nearly ripe, cracks reaching seed	3	0.44	80
Nearly ripe, hole in pericarp	4	0.48	96

Conditions during ripening

Additional berries were ripened at 15, 20 or 25°C, extracted after 3 weeks, and seed were germinated with or without GA (4 replicates of 100 seeds each) to test if temperature during ripening affected seed dormancy. In all three clones, 15°C ripening caused greater dormancy than did the 20 and 25°C treatments (Figure 1) in absence of GA suggesting that conditions during ripening exerted an effect on the physiological state of potato seed. However, with GA temperature differences were not clearly evident. The experimental design does not allow any conclusion as to whether temperature had a direct effect on dormancy or an indirect effect by causing differences in berry maturity.

Sorting seed by size

To evaluate the importance of within seed lot variation in size, a sample of DTO-33 op. seed was separated by sieving and visual inspection into two size categories averaging 0.564 and 0.432 mg per seed, respectively. No significant differences existed between size classes for either; germination measured in petri plates (four replicates of 100 seeds); or emergence from flats filled with a sand-peat moss soil mix (four replicates of 54 seeds).

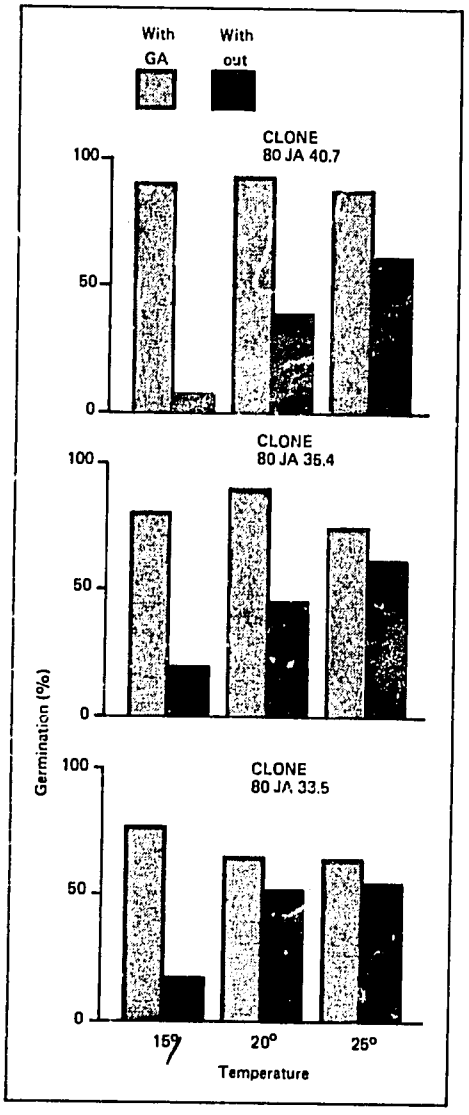

Figure 1. Effect of temperature during fruit ripening on dormancy of true seed.

However, large seed sown in the flats eventually produced plants with a significantly greater number of leaves (Table 2).

Treatment of seed with calcium hypochlorite

A series of experiments on germination of non-dormant seed of DTO-33 op. has led to the conclusion that immersing seeds in calcium hypochlorite solutions can cause an increase in germination rate, but not in final germination. To further test these observations, four replicates of 100 seeds were soaked for 2 hours in the following solutions:

Freshly prepared, filtered 2% calcium hypochlorite (pH = 12).

The above solution, but using seed which was hydrated 16 hours in a chamber lined with moist paper.

A 2% solution from which was aged artificially by prolonged heating and stirring.

Distilled water.

After treatment, seed were washed throughly with water, and then immediately placed to germinate in petri plates at 15°C.

Both fresh solutions of calcium hypochlorite caused marked increase in germination rate as compared to distilled water, while the aged solution caused a severe reduction (Table 3). Since the fresh solutions caused pronounced bleaching of the seed coat, it is hypothesized that the effect on germination rate is due either to oxidation of an inhibitor, or softening of the seed coat. The reduced germination with the aged solution suggests that as a hypochlorite solution loses chlorine over time, compounds are formed which can severely inhibit germination.

Conclusion

In all of these studies, treatments produced significant effects on germination or seedling growth, and these variables are simple enough to be incorporated into a seed production system. Since these treatments are only a few of a broad range used to improve seed quality of other crops, it seems reasonable to conclude that considerable potential exists, for improving potato seed quality. Precisely which treatments will prove most important remains to be demonstrated. However, one can easily imagine the day when true potato seed will be grown in fields located and managed to produce berries of outstanding quality. The seed will be extracted, sorted, treated chemically, and pelleted with nutrients and pesticides, and the final product will be packaged and stored under conditions which preserve the potential vigor. The development of this chain of production techniques represents one of the major challenges for true potato seed research in the years to come.

Table 2. Effect of seed weight on seed quality.

Characteristic	Large seed	Small seed	L.S.D. 05%
Seed wt. (mg)	0.564	0.432	
Germination in petri dishes (% at 12 days)	99.0	97.5	3.0
Emergence in trays (% at 12 days)	99.1	98.4	3.0
Leaves/plant (no. at 33 days)	5.6	4.9	0.4

Table 3. Seed germination as affected by soaking in calcium hypochlorite solution for two hours.

Treatment	Germination (%)			
	3 days	4 days	5 days	6 days
Fresh 2% $Ca(ClO)_2$	17	67	99	100
Fresh 2% solution with hydrated seed	31	72	99	100
Aged 2% $Ca(ClO)_2$	1	2	3	4
Distilled water	2	28	93	99

SEASONALITY OF MAJOR LEPIDOPTEROUS POTATO PESTS IN ISRAEL

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Abstract

The potato crop in Israel is attacked by two major lepidopterous pests found in warm climates. Spodoptera littoralis (Boisd.) is highly polyphagous and favours newly watered fields and succulent plants for oviposition and larval development. Phthorimaea operculella (Zell.), on the other hand, is a specific solanaceous pest, favouring dry substrates for oviposition and avoiding high relative humidity.

It is believed that Israel can serve as a model of the adaptation of lepidopterous insect pests to the potato crop in non-traditional climates.

The potato crop in Israel is not of very long standing. The two major lepidopterous pests attacking it, P. operculella, S. littoralis, attained their present status gradually. Until the 1930s potatoes were sown in November and grown as a winter crop, and thus damage by potential lepidopterous pests was avoided.

We shall deal first with the potato tuber moth, P. operculella, which is a specific solanaceous pest. It was considered a tobacco pest in this country (Bodenheimer, 1930), being active in summer when potatoes were not present.

In the 1930s the cultivation of potatoes was extended. Potato tuber moth damage was first observed in stored tubers, and later damage was encountered in exposed tubers in the field. Larval infestation of leaves followed, but occurred only occasionally. In the late 1930s and early 1940s two annual potato crops were introduced: spring and autumn, or spring and winter. This double crop gave rise to a mass of volunteer plants, which afforded host plants for the potato tuber moth throughout the year; as a result, populations increased. The large populations caused heavy damage to the spring crop; in the autumn, the foliage was infested during the growing season and the tubers escaped damage (S. Zimmerman-Gries - unpublished data).

P. operculella is a species that favours high temperatures and has no diapause. If conditions are favourable, it will develop continually without interruption. The gravid females are attracted to dry substrates for oviposition (Fenemore, 1978), and thus in dry climates populations are high. The phenology of P. operculella in a semi-arid irrigated area in Israel is shown in Figure 1. The populations are very low in winter, rising gradually in spring and building up to a peak in midsummer. This peak occurs when high night temperatures (25-30°C) coincide with an abundance or rich food for the larvae, in the form of exposed tubers in the field, before, during and following harvest.

The development period, which is dependent on climatic conditions and availability of suitable hosts, is thus very short at the high temperatures prevailing in the summer. Mating and oviposition take place shortly after emergence, with a resultant overlapping of generations.

The spring crop develops, as a rule, when the P. operculella population is low. The fields are well irrigated, the plants are succulent, and these microclimatic conditions do not favour oviposition by the potato tuber moth (Fenemore, 1978; Foot, 1974; Yathom, 1968). Toward harvest time, irrigation ceases, populations are high and potato fields dry, attractive and suitable to ovipositing P. operculella females. The crop is liable to be heavily infested if not protected.

The autumn crop is sown in September, when P. operculella populations are still high and may infest the fresh foliage, especially if the crop is not irrigated properly. Later, temperatures drop and moth populations dwindle. The crop is picked in January, when the population is very low and inactive.

The winter crop, sown in October, develops and matures during a season of cool temperatures (10-15°C) and low moth populations. Very rarely is the winter crop

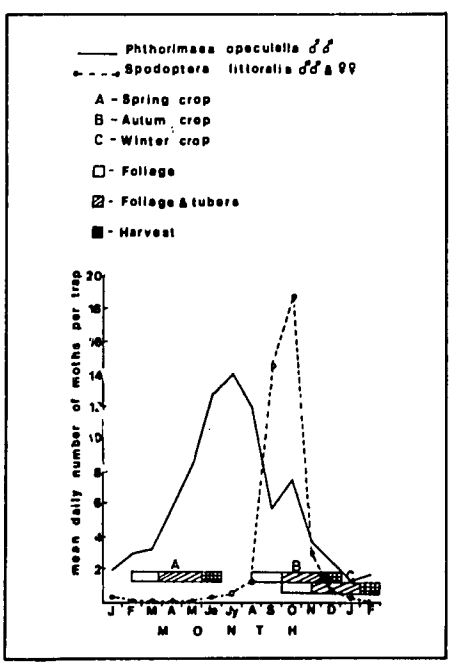

Figure 1. Number of moths caught during 1978 and 1980 in Gilat, Israel, in a semi-arid irrigated area.

infested, and then only if picking occurs during a hot spell.

S. littoralis is the other lepidopterous pest of potatoes in Israel. It is highly polyphagous and favours fairly high humidity. Its populations are high where irrigation is practiced, as moths are attracted to oviposit in newly watered fields (Bishara, 1934). In dry desert areas the pest population is low. (Wiltshire, 1957).

In this country S. littoralis was not an important pest in the 1920s, when irrigated field crops were the exception rather than the rule. Even then, it was anticipated that it would become a major pest if irrigation were to be extended (Bodenheimer, 1930). In the 1930s S. littoralis was already an important pest of vegetables and forage crops, but did not yet attack potatoes. Potatoes became a host for it in this country with the introduction of an autumn-sown crop.

In light trap catches carried out since 1959, S. littoralis populations were not uniform throughout the years, but high adult populations in traps coincided with high larval infestations (Yathom, 1971). Individual moths may be on the wing almost all year round, if temperatures allow, but populations start to build up with the onset of warm weather in May-June, reaching a peak in September-October, after which they drop.

The phenology of S. littoralis at Gilat, Israel, in a semi-arid irrigated area where potatoes are grown during two seasons of the year, is shown in Figure 1. The spring potato crop develops when S. littoralis populations are absent or very low, and thus damage is avoided. Occasionally, population build up starts early, and the spring crop may be attacked and its foliage destroyed. The mature larvae may then descend and attack the tubers before pupating, as happened in some fields in 1979.

Build up of S. littoralis populations takes place in all irrigated vegetables and forage crops, as well as in cotton.

The autumn potato crop is sown when S. littoralis populations are at their peak, and potato fields are irrigated frequently. In some areas potatoes are the only irrigated crop, and the plots are surrounded by drying cotton fields. The newly watered potato fields, with their succulent plants, attract heavy oviposition and consequently become heavily infested. Larval migration from drying cotton fields may also take place. Later temperatures drop, populations dwindle, and infestation stops.

The winter crop, sown in October, develops and matures during the cool season, when S. littoralis populations are absent or very low and inactive, and thus is not damaged.

Conclusions

When introducing potatoes into non-traditional hot climates, attention must also be paid to the endemic, polyphagous pests active in the region during the season planned for potato growth and harvest.

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PREDICTING YIELD PERFORMANCE

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The evaluation of large numbers of seedlings under different environmental conditions is a formidable task for breeding programs that attempt to serve broad geographic areas. It would be of considerable value if a predictive system could be developed that would identify inferior clones prior to distribution for testing.

A paper on the subject of yield prediction was presented to the "Planning Conference on Utilization of the Genetic Resources of the Potato, 1979". The present paper updates this research.

The particular data under discussion involves 8 cultivars tested at 9 sites (Table 1). Kennebec and Spunta were used as 'control cultivars' to estimate environmental effects at each site. The mean yield of these two cultivars for a site is taken as the measure of the environmental index for that site. Using this mean yield as the independent variable, the individual 'test cultivars' were regressed on the independent variable to develop a regression equation. Data from 4 sites (Brazil-79, Philippines-79, Turkey-79, and Canada-80) were used as 'control sites' for developing regression equations for each of the eight cultivars (Table 2).

Using these regression equations and using the values of the 'control cultivars' for the other five sites (Canada-79, Brazil-80, Pakistan-80, Tunisia-79, San Ramon-80) it is possible to make a prediction of the performance (yield) of each of the 'test cultivars' in each of the five 'test sites'. But, we have actually performed the trial at each of the 5 sites, so that we end up with an actual and a predicted yield for each of the 'test cultivars' at each 'test site'. One way of determining the usefulness of these values for predicting performance is to measure the correlation between the observed and predicted yield values.

Table 1. Marketable yield in tons/kg for eight cultivars tested over nine sites.

Cultivar	Brazil -79	Canada -79	Pakistan -80	Philippines -79
Kennebec	7.19	12.90	23.78	16.91
R. Burbank	7.44	5.41	15.82	7.69
TA-37	6.24	10.16	20.00	10.61
R. Pontiac	9.12	12.88	31.02	10.62
Bintje	3.88	3.16	24.04	11.85
DTO-28	16.90	12.63	23.24	12.16
Wauseon	10.10	10.52	19.69	9.88
Spunta	13.68	13.06	26.04	15.17
Ij[1/]	10.43	12.98	24.91	16.04

Cultivar	Turkey -79	Tunisia -79	San Ramon -80
Kennebec	22.10	18.04	7.39
R. Burbank	18.53	15.81	7.83
TA-37	16.29	17.07	5.52
R. Pontiac	32.81	19.52	10.77
Bintje	20.75	21.19	11.24
DTO-28	23.88	19.11	15.34
Wauseon	24.78	20.89	5.83
Spunta	27.01	21.63	11.49
Ij[1/]	24.56	19.84	9.44

Cultivar	Canada -80	Brazil -80
Kennebec	17.95	12.65
R. Burbank	12.48	9.02
TA-37	11.47	8.81
R. Pontiac	13.86	10.60
Bintje	12.27	12.47
DTO-28	13.24	16.90
Wauseon	14.73	11.25
Spunta	15.17	17.47
Ij[1/]	16.56	15.06

[1/] Ij = (Kennebec + Spunta)/2.

Table 2. Regression equations for eight cultivars based on data of four sites* and the average yield of Kennebec and Spunta as environmental index (Ij).

Cultivar	A ± BIj
Kennebec	16.04 ± 1.01 Ij
Russet Burbank	11.54 ± .82 Ij
TA-37	11.15 ± .71 Ij
Red Pontiac	16.60 ± 1.76 Ij
Bintje	12.19 ± 1.18 Ij
DTO-28	16.55 ± .58 Ij
Wauseon	14.87 ± 1.10 Ij
Spunta	17.77 ± .99 Ij

* The four sites are Brazil-79; Philippines-79; Turkey-79; Canada-80.

Table 3 presents intra-class (r_1) and inter-class (r_2) correlations for the 5 sites not used in deriving the regression equations. The r_1 is derived from the analysis of variance for each of the sites and a significant r_1 value indicates significant differences between cultivars. r_2 is the correlation between observed means and predicted values for each site. A significant r_2 value indicates the eight values in the observed and the eight values in the predicted correlate well.

Both r_1 and r_2 are highly significant for Canada-79, Pakistan-80, and Brazil-80. Both r_1 and r_2 for Tunisia-79 are not significant, indicating no differences were

Table 3. Intra-class (r_1) correlations obtained from analysis of variance and inter-class (r_2) correlations between observed means and predicted values.

Site		r_1	r_2
Canada	1979	9474**	8001**
Pakistan	1980	9526**	8550**
Tunisia	1979	2138 NS	5794 NS
San Ramon	1980	9287**	4276 NS
Brazil	1980	8913**	8159**

** Significantly different from zero AT P = 01; * AT P = 05.
NS not significantly different from zero.

observed between cultivars in the trial. The r_1 value for San Ramon-80 indicates that differences existed between cultivar performance, but the non-significant r_2 value indicates that our model failed to predict these differences. In 4 of the 5 situations the model predicted the actual outcome.

Figure 1 shows the association between predicted and observed values over the 5 sites. Canada-79, Brazil-80 and Pakistan-80 show good correspondence. No conclusive statement can be made for Tunisia because of non-significant trial results. The results for San Ramon-80 show poor correspondence.

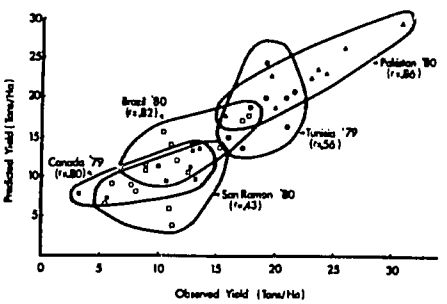

Figure 1. Relationship between observed and predicted values for 8 cultivars in 5 sites.

Discussion - It must be pointed out that this example used only two cultivars (Kennebec and Spunta) as controls to represent the impact of the environment. One would expect the efficiency of the model to increase when using an expanded array of controls.

The use of the model requires that data of quality be available from all control and test cultivars from all sites. This has in the past and will continue to be difficult goal to achieve.

The reasons why the model failed to predict the San Ramon-80 results are not understood. San Ramon is a unique lowland tropic environment and cultivars may respond quite differently at this site. This may indicate that a linear regression model is not to be the universal model. Perhaps certain sites will require the development of models specific for that site. The evidence obtained to date, however, cannot be taken as conclusive since an extremely small body of data is available. In addition, there is also the matter of choice of 'control cultivars' that will accurately reflect the environmental impact of a site. Sites may differ in their ability to serve as control 'sites'.

We feel that the approach and the model are promising and that further theoretical and experimental development are warranted. It is our intention to conduct a trial involving 8 controls, 15 test line and 8 sites during 1982-83.

The authors wish to thank CIP, Lima for the financial support of this research, CIP's Regional Research and Training Staff for arranging the trials and the national programs in 9 countries for conducting the trials.

PHYTOSANITATION IN SEED POTATOES

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Studies on virus epidemics in potato fields are frequently involved with the monitoring of vector and disease incidence. The majority of potato viruses are carried by air-borne insects. Therefore, flying and alighting aphids were recorded where the incidence of vectors has to be assessed. In most studies the incidence of aphids are counted using yellow-water 'Moericke traps' (Moericke, 1951; Zimmerman-Gries and Swirski, 1960), sticky traps (Broadbent et al., 1948) and suction traps (Tamada and Harrison, 1981).

Enzyme-linked immunosorbent assay (ELISA) for the detection of potato viruses is widely used in a number of laboratories (Casper, 1977; Marco, 1981a; Clarke et al., 1980). Recently ELISA was also used for detection of potato leafroll virus (PLRV) (Tamada and Harrison, 1981) and for potato virus Y (PVY) (Raccah et al., 1981), aphids (Robert, 1971), compared the relation between vector peaks and virus disease incidence in potatoes. Similar studies were carried out in Israel by us, (Zimmerman-Gries and Harpaz, 1967). The knowledge collected served for planning regions, period of sowing, and control of seed potatoes. The following control measures were proposed in order to suppress virus epidemics in potatoes.

Breeding for virus resistance

To the best of our knowledge no commercial cultivars carrying high levels of virus resistance are available. More work should be done to develop lines that will withstand aphid-borne viruses.

Avoidance of infection

For the production of seed potatoes it is of vital importance to avoid areas with obvious high aphid populations during the growing season. Such conditions are often found at high altitudes (Zimmerman-Gries and Harpaz, 1970) or isolated places (Marco, 1981c). Alternatively the destruction of potato haulms in seed potato crops before maturity is practiced in the Netherlands and Switzerland to reduce virus spread, especially when aphid populations are high at the end of the season (Salzman, 1953). Aphid trapping in combination with tests of aphid inoculativity are sometimes used to determine locations and seasons where and when to grow seed potatoes.

Testing for rates of the incoming virus infection is presently done with indicator bait plants.

Oil Sprays

Oil sprays are used for non-persistent viruses when insecticides do not reduce infection. It was found that the use of mineral oil has an effect on the decrease of non-persistent virus dissemination in potatoes (Allen, 1965; Bradley et al., 1966; Wenzl and Foschum, 1973). In those studies the virus control ranged between 30 to 88%.

Sticky yellow sheets

A marked reduction of virus infection in potatoes was reported by Zimmerman-Gries (1979), the percentage of PLRV affected tubers from protected plots was between 2 and 6% while in the unprotected control it was between 17 and 29%. There was also a reduction in the spread of both potato non-persistent viruses PVY and alfalfa mosaic virus (AMV).

White nets

A novel approach to decrease virus dissemination in peppers was attempted by Cohen et al. (1978), using 2-8 mesh white nets that were placed at least 0.5 m above and around the plots. As the aphid's vision is apparently limited to less than 50 cm, these nets seem to obscure the plants from the aphids. Representative results with nets of different colors were used. In the control pepper plots virus incidence reached 95% after 77 days, whereas in plots under white, yellow and gray nets virus incidence was 2%, 13% and 45%, respectively.

In potatoes, covers of white coarse net 2.5 x 8.0 mesh per inch square (1 x 3.3 mesh per cm square) reduced alighting aphids to about 2% of those trapped in unprotected plots but increased by factors of about 5 to 6000 the number of apterae. PLRV incidence was greatly reduced in protected plots provided that no secondary infection occurred under the net. In plots planted with secondarily PLRV- infected seed subsequent incidence under the net was even higher than in the unprotected controls (Marco, 1981b).

This approach could become most important for producing high-value propagation materials, although it has to be evaluated under different climatic (e.g. wind) and light conditions, and especially when the aphid population pressure is relatively high.

Barrier plants

Barrier plants have often been suggested for protecting plants from non-persistent viruses, and aphids will lose the virus when they probe on the barrier plants. Sunflowers as barrier plants were used to protect pepper from PVY in Florida (Simons, 1960). In Israel, sorghum as a barrier was used in experimental potato plots and some reduction in PVY was noticed (Zimmerman-Gries and Harpaz, unpublished data). However, the use of barrier plants under commercial field conditions is generally not compatible with the present cultivation practices.

Conclusions

As a result of the inefficiency of vector control by insecticides and the slow progress in breeding for virus resistance, some of these unconventional methods, single or in combination, may become of practical use for growers of high-value seed potatoes as virus-tested propagation stock.

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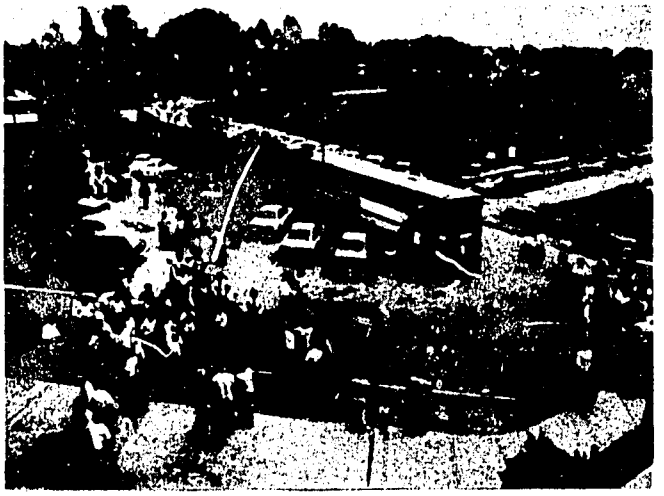
President Belaunde invited members of the Congress to visit the Presidential Palace.

Coffee break at the Sheraton Hotel.



Arrival of tour busses at the CIP headquarters for observation of the field, greenhouse and laboratory facilities.

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