AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

# BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

**1. SUBJECT CLASSIFICATION**

A. PRIMARY: Serials AF00-0200-0000

B. SECONDARY: Food production and nutrition--Sugar and starch crops--Potatoes

**2. TITLE AND SUBTITLE**

Annual report, 1977

**3. AUTHOR(S)**

(101) CIP

**4. DOCUMENT DATE**: 1978

**5. NUMBER OF PAGES**: 161p.

**6. ARC NUMBER**: ARC 633.491.I61a -1977

**7. REFERENCE ORGANIZATION NAME AND ADDRESS**

CIP

**8. SUPPLEMENTARY NOTES** *(Sponsoring Organization, Publishers, Availability)*

(Research summary)

**9. ABSTRACT**

**10. CONTROL NUMBER**

PN-AAG-543

**11. PRICE OF DOCUMENT**

**12. DESCRIPTORS**

Potatoes
Yield

**13. PROJECT NUMBER**

931097300

**14. CONTRACT NUMBER**

AID-ta-G-1181 GTS

**15. TYPE OF DOCUMENT**

AID 590-1 (4-74)

633.491
I61a
1977

# annual report

# CIP

## 1977

PN-AAG-543

# annual report

# 1977

**international potato center**

*Apartado Postal 5969 Lima-Perú*
*Cables: CIPAPA*

Hilling operation at the new land site in San Ramon, Peru

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**COVER PHOTO**

*Marketing scene in Huancayo, Peruvian Highlands.*
*Photograph by Jean Pierre Lekeu*

*The International Potato Center, also known as Centro Internacional de la Papa (CIP), is a Scientific Institution, autonomous and non-profit making, established by means of an agreement with the Government of Peru with the purpose of developing and disseminating knowledge for greater utilization of the potato as a basic food. International funding sources for technical assistance in agriculture are financing the Center.*

The following are excerpts from a speech given by Dr. Richard L. Sawyer, Director General of CIP, on April, 28, 1977 during CIP's Fifth Anniversary celebration.

## *FIFTH ANNIVERSARY & DEDICATION OF FACILITIES PRESENTATION*

*This week we are celebrating the Fifth Anniversary of the International Potato Center. New facilities are also being dedicated that have been constructed to help better respond to our mandate which is "to rapidly develop, adapt, and expand the research necessary for the technology to solve priority problems limiting potato production in developing countries."*

*In these next few minutes, I shall briefly try to identify how we have evolved, what our program is, who our donors are and what we are ready for and doing for developing countries around the world at the present time.*

*CIP's history started in 1966, when the Peruvian Ministry of Agriculture initiated a potato commodity program with financial and technical assistance from North Carolina State University through a US-AID grant. This association led to discussions concerning methods for exploiting the tremendous genetic wealth that existed in the Andean region of South America to help solve the world food problem which was becoming increasingly apparent during the late 1960s.*

*By 1970 sufficient interest was stimulated to justify the development of a first proposal which was presented to US-AID. The Peruvian Government and agricultural officers of the Dutch, British and German embassies in Peru indicated an active interest in the development. The Rockefeller Foundation indicated they were willing to join its international Potato Program to what was being formed in Peru.*

*In 1970 US-AID provided planning money for a two-year period to activate an International Potato Center.*

*In January 1971 an agreement was signed between the sponsoring institution, North Carolina State University, and the Minister of Foreign Affairs representing the Government of Peru that permitted the location of an International Potato Center in Peru.*

*During this same period, the Consultative Group on International Agricultural Research (CGIAR) was being formed, starting with the four international centers already activated by the Ford-Rockefeller Foundations and with the possibility of adding additional centers as justified.*

*In 1972 CIP became the first new center to join the CGIAR network and first funding as an international center was received in mid-1972. There are now 11 international centers in the network of the CGIAR.*

*CIP's strategy for development and serving its mandate has been:*

- *To identify the priority research problems for potato production and improvement in developing countries.*
- *To identify to what extent funding would permit CIP's involvement with these problems.*
- *To identify which portion of this priority research was CIP uniquely qualified to conduct and to identify what could be accomplished equally well at other institutions.*
- *To involve through research contracts and international planning conferences as many institutions as possible around the world where facilities and capabilities already existed for helping solve the priority problems for potato improvement in developing countries.*

- *To develop regional locations on core program funding for the initial research transfer, the multiplication, evaluation, adaptation and redistribution to surrounding countries in order to get applicable technology to country doorsteps.*
- *To develop training programs at CIP headquarters and in the regional programs in order to have capable receivers of CIP technology within country programs.*

*In mid-1972 upon receiving its first money as an International Center, CIP held an international planning conference entitled: "Prospects for the Potato in the Developing World." Senior potato scientists from both developed and developing countries were brought to Lima to help determine what were the priority potato problems in developing countries and what research CIP should be initiating. As a result of these discussions, nine major research thrusts were identified as priority work. CIP's major research efforts are concentrated in these nine thrusts which are systematically evaluated through periodic international planning conferences and changed as indicated by progress and the identification of changes in priorities.*

*From its initiation, CIP has attempted to get its roots into as many institutions as possible around the world to help with the development of needed technological packages and their transfer. The two principal strategies utilized are international planning conferences and research contracts.*

*For each of the major research thrusts and their components, CIP holds an international planning conference every three years. These are rotated so that each year there are an average of three. At each conference a five-year plan for CIP activities is developed after taking into consideration the progress made and present status of research with the problem. A group of 10 to 15 senior scientists from developing countries working on the specific research problem are brought together for a week of discussions with CIP staff. As a result of these conferences there tends to be a coordination of research activities among the institutions participating and CIP receives a great deal of research help at little if any direct cost.*

*From its initiation, CIP established the policy of conducting a portion of its priority research for developing countries at institutions where facilities and capabilities already existed. Through such linkages CIP was able to move into breeding programs already underway, catalize them to an international dimension and have research material ready*

*for distribution in a very short time. Contracts are with institutions where the facilities and scientists are already in place, and CIP provides funding for expandable supplies, extra technicians, and international travel to link the work directly to CIP and to developing countries. As specific pieces of work are completed, contracts are terminated and new ones initiated. Such a system gives excellent flexibility for changes in concentration as priorities change.*

*Due to the problems encountered in the multiplication and distribution of a vegetatively propagated crop such as the potato, CIP has regionalized a portion of its core research program. Thus CIP has the ability on core program funding to get its technology into the various regions of the world for multiplication, evaluation, adaptation and redistribution to country program doorsteps. At this point CIP's direct responsibility stops.*

*The seven regions of the world where CIP has research and training staff located are:*

*I South America – Headquarters – Peru*
*II Central America and the Caribbean – Headquarters – Mexico*
*III Tropical Africa – Headquarters – Kenya*
*IV Middle East and North Africa – Headquarters – Turkey*
*V Southwest Asia – Headquarters – Pakistan*
*VI Central Asia – Headquarters – India*
*VII Southeast Asia – Headquarters – Philippines*

*CIP's value will eventually be determined by the changes which have resulted in a countries food supply due to an association with CIP and the technology it has made available. This credibility must be established in the fields of potato growers in developing countries. This is where the final evaluation must take place.*

*I would like to thank the many people that have been responsible for the institutional maturity which CIP has achieved in such a short time.*

*First in importance is the faith and backstopping of donors who were willing to invest in a new approach to the establishment of an international center. Those donors over the past five years are listed in alphabetical order as follows:*

*Australia*
*Belgium*
*BID (International Development Bank)*
*CIDA of Canada*
*Denmark*
*Ford Foundation*
*Germany*
*IDRC of Canada*
*Netherlands*
*Rockefeller Foundation*
*Sweden*
*Switzerland*
*Saudi Arabia*
*United Kingdom*
*United States*
*World Bank*

*I would like to thank the scientists of international caliber who were willing to leave secure and comfortable positions in established institutions to join this CIP venture. We presently have 16 nationalities representing all major continents on the staff.*

*I would also like to thank a Board of Trustees, all of whom were working members devoting several weeks a year without pay to help in CIP's development and management. We have an International Board of Trustees with no more than two members at a time from any country. Two of the board members have been active since before the initiation of CIP, Dr. Mariano Segura of the Ministry of Food and Dean Jack Rigney of North Carolina State University and deserve special attention at this inauguration as they will be retiring as of this week. They have served as President and Secretary of the Board of Trustees for the last five years.*

*And last but not least, a very special recognition must go to the Peruvian Government for their fine cooperation, the donation of our original building which helped catalyze interest of the CGIAR, the donation of land in several locations in Peru, on the coast, in Huancayo and in the jungle, and the excellent support of the many Ministries in clearances necessary for managing an international operation headquartered in Peru. Special thanks must go to the fine cooperation which has been established with the National Agrarian University, the Experimental Station in La Molina, and the staff of CRIA I.*

*In summary, we at CIP are announcing today what has been established in the past five years and is already helping improve the potato around the world. We go where opportunity exits. We do not push ourselves anywhere.*

*But we gladly welcome your development of a suction force in your respective countries which will start the flow of training and research help from CIP, as justified by the importance the potato can play in your respective countries. CIP and its staff are nearby and waiting.*

*Unless we are utilized, unless our technology is being tried and evaluated in the fields of growers in your countries, we are working in vain. Only through association with developing country programs and the bilateral agencies helping them can CIP technology for potato improvement get into growers fields and the investment in this center be justified.*

* * * * * * * * * * * * *

*Since making these remarks one year ago, I have been reflecting further on the future of CIP.*

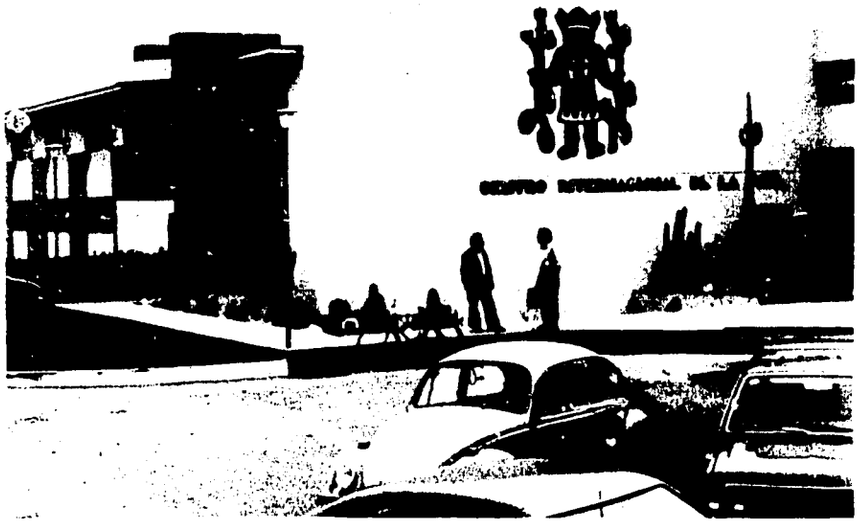
*CIP's institutional development as a Center has been completed during the initial five years. During the second five year period, the relevance of CIP to the world food problem and world nutrition needs must be established effectively.*

*In the area of the world where population and food are a major problem, the potato is mainly a luxury vegetable. If CIP is to be relevant, the technology must be developed to make the potato a low-cost food for subsistance growers in Southeast Asia who possibly may have no more than 50 potato plants growing in their garden along with other vegetables. The value of the potato nutritionally is already well established as is its acceptability as a food among most cultures. The quality of potato protein is superior to all other major plant foods. The role the potato could play in balancing diets, if it becomes available as a low-cost food, needs to be thoroughly explored.*

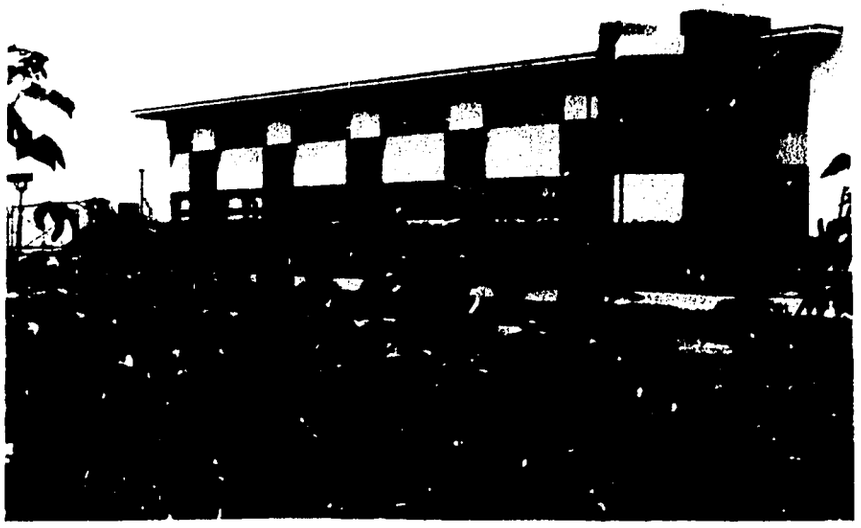
*Imaginations must be stretched in the development of the technology to make the potato a poor man's food. Exciting possibilities exist, such as learning how to produce edible potatoes directly from botanical seed. CIP has considerable research in progress in the development of such technology and recently learned that mainland China is already growing over 10,000 hectares of consumer potatoes annually from botanical seed. Such a technique could drastically reduce seed costs which presently are over 50 percent of the total cost of production of potatoes. This is an example of the technology being developed and transferred and applied as CIP becomes more relevant to the world food problems.*

Richard L. Sawyer

**Richard L. Sawyer** — *Director General*
*Centro Internacional de la Papa*



Entrance and side view of the recently completed training wing in La Molina. The emblem of CIP represents a tapestry figure holding healthy and diseased potato plants. It is from the Nazca Culture of Peru (4th Century A.D.).



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## CIP DONORS – 1977

Starting from a group of only three donors in 1972, the following donors contributed to the financial support of the International Potato Center during 1977.

| | Core Budget | Special Projects Budget |
|---|---|---|
| – *Interamerican Development Bank (IDB)* | X | X |
| – *Canadian International Development Agency (CIDA)* | X | X |
| – *Danish International Development Agency (DANIDA)* | X | |
| – *Ford Foundation* | | X |
| – *Government of Australia* | X | |
| – *Government of Belgium* | X | |
| – *Government of Federal Germany* | X | X |
| – *Government of Saudi Arabia* | X | |
| – *Government of Switzerland* | X | X |
| – *Government of The Netherlands* | X | X |
| – *IBRD/IDA* | X | |
| – *International Development Research Centre (IDRC)* | X | |
| – *Sweden International Development Agency (SIDA)* | X | |
| – *United Kingdom Overseas Development Ministry (UKODM)* | X | |
| – *United States Agency for International Development (USAID)* | X | |

## INTRODUCTION

CIP's integrated research program includes research carried out by CIP scientists in Lima and in developing countries of the tropics and subtropics, supported by contract research at selected institutions in both developed and developing countries.

The research is organized on the basis of formally defined projects grouped into nine research thrusts. Progress in fulfilling thrust objectives is reviewed every three years during international planning conferences. Invited experts set out guideline recommendations for a subsequent five-year period based on progress, priority regional needs, and general state-of-the-art considerations.

During the Fifth Anniversary Year, 43 research projects were supported by 26 research contracts at 21 institutions. CIP also sponsored three planning conferences in Lima to review progress in Socioeconomics, Virus Control, and Breeding and Genetics. To date 14 planning conferences involving 112 experts from 27 countries have provided guidance to CIP scientists in their efforts to efficiently focus on priority research to overcome production constraints in developing countries.

### Quinquennial Review

A Review Commission appointed by the Technical Advisory Committee of the Consultative Group on International Agricultural Research (CGIAR) conducted a five-year review of CIP research during December, 1976. Members of the Review Commission included:

Prof. Dr. J. G. ten Houten (Chairman)
Wageningen, The Netherlands

Dr. T. F. Carroll
Washington, D. C., USA

Dr. J. M. Hirst
Long Ashton, England

Dr. R. W. Hougas
Madison, USA

Dr. Hari Kishore
Simla, India

Dr. C. Valverde S.
Lima, Peru

Mr. B. N. Webster (Secretary)
FAO, Rome

Dr. J. K. Coulter (Observer)
Washington, D.C., USA

CIP has taken appropriate action with regard to the issues, conclusions and recommendations presented in the Report of the TAC Quinquennial Review Mission. Appreciation is expressed for the valuable contribution of the review mission in their assessment of the scientific activities of CIP.

## SUMMARY

**Thrust I** – Approximately 10,000 of 13,000 primitive potato cultivars in the germ plasm collection have been classified; 1,575 duplicates were removed from field maintenance and stored as botanical seed in 1977. Scientists on five expeditions collected 200 wild, tuber-bearing specimens; 63 have been classified as belonging to 30 different species.

**Thrust II** – Single and combined resistances to late blight, bacterial wilt and wart diseases were verified under severe field conditions in selected countries. Heat-tolerant clones have been shown to have lower dark respiration levels than heat sensitive clones. Improved heat-tolerant hybrids yielding one kg per plant in 60-70 days have been distributed to nine countries. Consistent progress has been made in breeding and field testing cold-tolerant clones for the highland tropics.

**Thrust III** – Many blight resistant clones have been developed that withstand the severe epidemics at Toluca, Mexico. At the International Late Blight Test in Mexico, 1,048 selected clones were screened for blight resistance. Seedling screening tests for wart and smut have been developed to facilitate rapid assay for resistance.

**Thrust IV** – The Peruvian program released the bacterial wilt resistant variety "Molinera" which has special characteristics for small farms. Good wilt and root-knot nematode resistance has been identified in *Solanum sparsipilum*. CIP has assembled more than 90 isolates of the wilt bacterium; both races 1 and 3 have been isolated from virgin jungle soil.

**Thrust V** – Steady progress has been made in breeding and screening for potato leaf roll virus and "Y" virus resistance. Characterization of three new viruses was continued. A program to screen for spindle tuber viroid was initiated. The latex test was introduced for all routine serological checks; a comparative evaluation of the ELISA test was commenced. A new Joel JEM 1005 model transmission electron microscope was installed on an appropriate seismic resistant base. A planning conference on control of potato viruses was held in 1977.

**Thrust VI** – Two clones of *S. andigena* have been identified with broad cyst nematode resistance. In trials in Peru, 360 of 2,500 species intercrosses from Cornell showed promising resistance to selected cyst populations. Only 19 of 1,937 germ plasm clones had resistance to root-knot nematodes; intercrossing and outcrossing of selected genotypes is planned to utilize these resources. Further data has confirmed resistance to aphids by entrapment of glandular hairs on foliage. A synthetic sex attractant was very efficient in attracting male tuber moths to simple water traps in the field.

**Thrust VII** – Physiological attributes contributing to heat, cold and drought stress tolerance continued to receive attention. The capacity to produce food in two to six months in a temperature range of 43° C, a latitude range of 100°, an altitude range of 4,300 m, and a 9-hour difference in daylength range is rivaled by few crops. Intercropping and fertilizer studies in divergent ecological zones were continued throughout the year.

**Thrust VIII** – Storage research utilizing local materials was carried out in Peru and Kenya with favorable results. Solar dehydration studies resulted in further refinement of "black box" technology. A wide range of routine nutritional analyses in support of various projects were active. A further need to publicize the excellent nutritional quality of potato, particularly protein, has been indicated.

**Thrust IX** – Expanding export of useful virus-tested breeding material to CIP regional programs was emphasized. Further efficiency through refinement characterized the tissue culture program. A minimum growth storage technique requiring only one transfer of tissue per year was developed. Air shipment of aseptic tissue *in vitro* was evaluated.

## COLLECTION AND CLASSIFICATION OF TUBER-BEARING SOLANUMS

The exploration and collection of cultivated indigenous potatoes has been completed two years before the projected date, with the exception of work in Mexico and a few remote ecological areas in the South American Andes. More than 10,000 of the approximately 12,000 accessions collected have been classified by morphological criteria. About 1,575 duplicates representing 191 different morphological types have been identified. After obtaining botanical seed for storage, these duplicates have been eliminated from vegetative maintenance.

**Table 1 – Summary of classified species of primitive potato cultivars ***

| Species | 2n | No. of accessions | Percent |
|---|---|---|---|
| *S. stenotonum* | 24 | 1,270 | 12.6 |
| *S. goniocalyx* | 24 | 310 | 3.1 |
| *S. phureja* | 24 | 290 | 2.9 |
| *S. ajanhuiri* | 24 | 60 | 0.6 |
| *S.* x *chaucha* | 36 | 720 | 7.2 |
| *S.* x *juzepczukii* | 36 | 159 | 1.6 |
| *S. tuberosum* | | | |
| ssp. *andigena* | 48 | 6,897 | 68.7 |
| ssp. *tuberosum* | 48 | 161 | 1.6 |
| *S.* x *curtilobum* | 60 | 170 | 1.7 |
| | | 10,037 | 100.0 |

* Identified in December, 1977, from Argentina, Bolivia, Colombia, Chile, Ecuador, Peru and Venezuela.

Prior to the elimination of duplicate accessions from field maintenance, synonymy is verified by slab electrophoresis at the Institut für Biochemie, Biologische Bundesanstalt, Braunschweig, Germany. Tuber proteins of each duplicate morphotype are separated electrophoretically and electrophoretic protein patterns are compared. Under standardized conditions each genotype has its own characteristic electrophoretic pattern. In general there has been agreement to verify duplicate morphotypes by protein spectra; to present 960 clones have been examined by electrophoresis.

**Slab electrophoretic protein spectra of duplicate and dissimilar morphotypes.**

Because of the significant progress made in the collection of primitive cultivated species, collecting expeditions have been initiated for wild tuber-bearing potato species. Priorities based on specific criteria for collecting wild species were established by a group of eight international experts at a 1976 planning conference. As a result of these priorities, five field expeditions were conducted in Peru and one in Venezuela during 1977. Of the nearly 200 specimens collected, 63 have been classified as belonging to 20 different species in eight series. Some of the newly collected wild species represent the only living specimens in germ plasm collections around the world, collected in the type locality.

*Solanum colombianum* **Dun. was recently rediscovered in the region of Tovar, Merida State, Venezuela.**

As a result of research carried out in association with the University of Birmingham, U. K., a more definitive understanding of the interrelationship among *S. juzepczukii*, *S. curtilobum* and their common progenitor, *S. acaule*, has been established. These frost-resistant bitter potatoes contain the glycoalkaloids alpha-solanine and alpha-chaconine, as do *tuberosum/andigena* gene pools. These bitter potatoes also contain tomatine and alpha and beta solamarine. Studies have established that *S. acaule* is the source of such alkaloids. *S. acaule* families with low total glycoalkaloid content transmit low levels in crosses with cultivated diploids. *S. acaule* clones with frost resistance to -5° C, as well as resistance to potato cyst nematodes, late blight and bacterial wilt, have been identified.

Breeding techniques have been developed by which *S. acaule* germ plasm can be introduced into the *tuberosum/andigena* gene pool. It has been established that it is preferable to evaluate parental forms before breeding to reach a new level of ploidy. The combining ability of parental lines is very important in making crosses involving different ploidy levels.

View overlooking the restored hacienda buildings at CIP's La Victoria farm in the Mantaro Valley, Peru.

## MAINTENANCE, DISTRIBUTION AND UTILIZATION OF TUBER-BEARING SOLANUMS

### Maintenance

One of the responsibilities assigned to Thrust II is the maintenance of a world collection of potato germ plasm in a usable form. During the 1976-77 growing season, approximately 6,000 accessions were maintained in the field at CIP's experiment station in Huancayo. Open-pollinated seed of about 5,000 accessions were collected to replace seed in storage, either with low viability or few seeds per accession. About 4,000 native cultivars from Argentina, Bolivia, Chile, Ecuador, Guatemala, Venezuela and southern Peru were incorporated into the 1977-78 field maintenance program following a two-year quarantine.

In cooperation with the International Board for Plant Genetic Resources, a list of descriptors and descriptor states has been developed. All available documentary information relating to the entire cultivated collection is being stored in the computerized data management system of the Information Sciences/Genetic Resources Program at the University of Colorado, Boulder.

### Distribution and Utilization

In the development of a distribution and testing network, tubers of virus-tested clones, botanical seed, tuber families and multi-meristem cultures were exported from CIP during 1977. Selected clones were also shipped directly from CIP contract research programs in the United States and Europe. In recent agreements with Australia, Canada and the Netherlands, arrangements have been made for freeing selected stock of disease to permit acceptance by quarantine services in developing countries. As part of CIP's Regional Research and Training (RR & T) program, regional centers for potato germ plasm testing and distribution have been established in five of seven regional centers. Distributed for evaluation and use in breeding from October 1976 to October 1977 were a total of 3,512 tuber samples and 450 seed lots from the germ plasm collection. A provisional computerized inventory listing accessions with specific resistance to selected pathogens and pests has been prepared for distribution to potato researchers.

In cooperation with the Mexican National Potato Program, a bank of 259 clones resistant to late blight was maintained during 1977. From this collection 1,111 samples were distributed to various countries for further blight testing; 23 selected clones were sent to 17 countries for yield trials. Seven-thousand seedlings obtained from field resistant parents at CIP-Lima were evaluated in the International Late Blight Trial at Toluca Valley, Mexico, along with 1,048 clones from the Netherlands, Germany, India, Sweden and the United States. Also in conjunction with the Mexican program, breeding stocks from developed countries and CIP clones with outstanding blight resistance were made available in seed or tuber form for maintenance and further evaluation. Through a collaborative project with the Research Institute for Plant Protection, Wageningen, the Netherlands, selected blight-resistant clones from the Mexican CIP collection are freed of virus before being sent to developing country quarantine facilities.

Late blight trials were carried out in Nepal with 25 clones distributed from Mexico. Possibly because of similar latitude and environmental conditions, selected clones of *Solanum tuberosum* performed very well in initial 12-plant trials. The four best clones averaged more than 0.8 kg per plant, a four-fold greater yield than local checks. Ten advanced Mexican clones in second year trials produced average yields of 25 t/ha, the best yielding 34 tons. The standard variety, "Kufri Jyoti", yielded 18 tons while the European variety "Jaerla" yielded only six tons.

In a trial at Nigale, Nepal, 17 clones from CIP's "virus-free" program, 10 clones from a Cornell contract and three clones from the National Potato Development Program were evaluated for resistance to late blight, yield, and resistance to hail injury. The Peruvian variety "Mariva", similar in general characteristics to the accepted local round red variety, was outstanding in performance and yielded an estimated 50 t/ha.

Intensive screening for potato wart *(Synchytrium endobioticum*, biotype I) was also carried out in Nepal at Rolekhani, in cooperation with the Integrated Hill Development Project. Dual resistance to wart, as well as late blight, was verified under Nepalese field conditions in CIP material. The Mexican clone CFU (CIP 720047) was selected for outstanding blight resistance, wart immunity, hail tolerance and yield (30 t/ha).

In addition to late blight trials in Mexico and Nepal, field trials for blight resistance were carried out in Turkey, South Korea and Costa Rica. Trials in Costa Rica involved the dual evaluation of late blight and bacterial wilt *(Pseudomonas solanacearum)* under a range of tropical environments at altitudes from 600 to 3,000 m.

At a site in Turrialba, Costa Rica, where no solanaceous crops had been previously grown, bacterial wilt appeared 18 days after planting and developed very rapidly (Fig. 1). Only 11 of 207 clones survived to harvest, which was indicative of the disease severity. Three of these clones, CIP 676180, CIP 676101 and Cruza 148 had good adaptation and appeared resistant to bacterial wilt. The remaining eight clones were wilt tolerant and yielded up to 1.1 kg/plant. In another trial at Turrialba, 66 out of 520 clones were selected under severe late blight and bacterial wilt conditions. Trials at Turrialba have proven useful in testing CIP material for tropical adaptation as well as combined late blight-bacterial wilt resistance. At the Llano Grande site (volcano Irazú) at 2,000 m, early blight *(Alternaria solani)* was severe for some clones under 1977 tests.

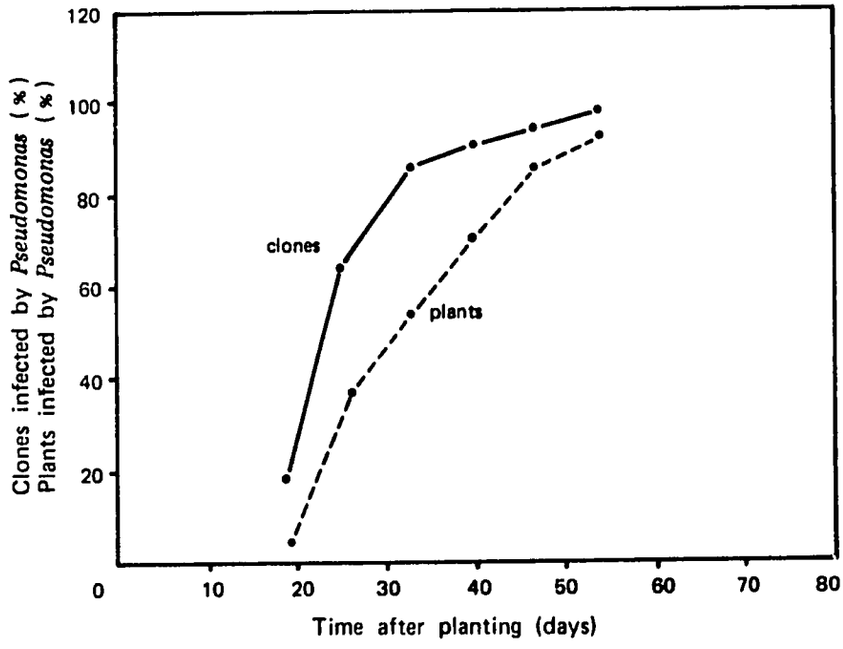



**Fig. 1 — Average increase of bacterial wilt in 5-hill plots of 207 clones, Turrialba Costa Rica.**

The second year of selection trials continued in Ethiopia, in CIP's Region III, in cooperation with the College of Agriculture, Addis Ababa University and the Institute of Agricultural Research. Attention was focused on yielding capacity, blight resistance, tuber and vegetative characteristics and maturity of 376 clones in the fourth cycle of selection. Sixty-three varieties, advanced selections and new clones were grown in replicated trials; about 25 percent yielded more than 40 t/ha and about half yielded over 30 t/ha. Nine stations in Ethiopia cooperated in the evaluation trials of selections generated from the screening program.

Through a research contract, trials were conducted at 10 locations during 1976-77 by the Peruvian Potato Research Program. At altitudes between 200 and 3,300 m, 2.3 percent of 1,964 diploid clones yielded more than 20 t/ha, 34.6 percent between 10-20 tons and 63 percent less than 10 tons. Dry matter content ranged between 25.0 and 36.3 percent and the percent of total protein varied between 7.5 and 15.5 percent (Table 2). Tuber texture, flavor, flesh color and depth of eyes were also evaluated in selected diploid clones. Material from the program was distributed widely in Peru as well as to CIP associates in Argentina, Bolivia and South Korea.

**Table 2 — Average yield, dry matter and total protein in selected diploid clones**

| Clone | Yield per plant (kg) | Percent | |
|---|---|---|---|
| | | Dry matter | Total protein |
| 3D80-35 | 1.6 | 29.5 | 9.0 |
| 3D80-52 | 1.4 | 29.2 | 8.1 |
| 5D32-41 | 1.4 | 35.0 | 8.8 |
| 3D5-1 | 1.3 | 28.6 | 9.8 |
| 3D80-23 | 0.6 | 36.3 | 10.7 |
| 5D232-41 | 1.4 | 35.0 | 8.9 |
| 5D41-41 | 0.9 | 34.3 | 8.1 |
| 3D80-43 | 1.1 | 33.8 | 7.5 |
| 5D370-41 | 1.0 | 25.6 | 15.5 |
| 5D264-41 | 0.5 | 25.0 | 12.7 |
| 5D238-41 | 0.6 | 28.9 | 12.5 |
| 5D256-41 | 0.6 | 28.1 | 12.1 |

Contract research at North Carolina State University was continued during 1977 for the utilization of cultivated diploid species. In a breeding program utilizing recurrent selection, the heritability of dry matter content was investigated in a high dry matter population of 400 diploid clones. Selected parents were intercrossed and analyses of specific gravity made to estimate narrow-sense heritability. The results (Table 3) indicate that heritability for specific gravity is in the 0.4 to 0.6 range.

**Table 3 — Analyses of heritability of specific gravity for selected clones grown at two sites in 1977**

| Method of analysis | Sites 1 | Sites 2 | Combined | Average |
|---|---|---|---|---|
| Realized heritability | .404 ± .088 | .384 ± .086 | .396 ± .086 | .395 |
| Parent offspring regression | .739 ± .031 | .618 ± .068 | .699 ± .053 | .679 |
| Half-sib analysis | .641 ± .332 | .301 ± .176 | .276 ± .208 | .406 |
| Average | .595 | .434 | .450 | .493 |

Clones of various tropical short-day potato species failed to tuberize under long day conditions. Therefore, it was necessary to use breeding and selection techniques to develop more widely adapted daylength neutral lines. In research at North Carolina, populations of the diploid species *phureja* and *stenotomum* have been interbred for six cycles and selections made for clones which tuberize under a wide range of photoperiods.

Daylength neutral families are now being screened for the production of 2n gametes to facilitate the incorporation of their valuable genetic traits with *S. tuberosum*. In breeding studies with *phureja*, which has no tuber dormancy, and *stenotomum*, with a pronounced long tuber dormancy, progress has been made in shifting the mean length of tuber dormancy.

Research is continuing in the identification of new diplogynoids and diploandroids as sources of non-reduced gametes in diploid *stenotomum/phureja* populations. In examination of 51 stn x phu families, 158 clones were found to have "2n" pollen, while 264 clones had "n" pollen. Parallel spindles have been identified (clone 66P 10.10 stn x phu) in Anaphase II, indicative of first division restitution. In various crosses involving diploandroids, in 50 of 250 $F_1$ seedlings examined to present, 22 triploid and 28 tetraploid clones have been identified; no diploids have been observed.

In contract research at the I. v. P. Agricultural University, Wageningen, the Netherlands, progress has been made in increasing the utility of genes from wild Mexican *Solanum* species with resistance to *Phytophthora*, *Pseudomonas*, and *Alternaria*. A new approach has resulted in the production of 150 hybrid plants derived as follows: *S. pinnatisectum* x *S. bulbocastanum*, doubled by colchicine to tetraploid $F_1$, which were then crossed to *S. acaule* females. Subsequent crossability with *S. tuberosum* is difficult, although with dihaploid *tuberosum* 10 berries were obtained in 1977. Many berries also were obtained during 1977 from quadruple hybrids: ((doubled *(S. vernei* x *S. bulbocastanum)* x *S. longipedicellatum*)) x varieties (and diploids). A number of other successful complex crossings were made in 1977. In other research, viable monohaploids were obtained from *S. verrucosum* and from *S. tuberosum* dihaploids x *S. verrucosum*. Crossing of doubled monohaploids with a fertile dihaploid produced uniform, vigorous, and fertile $F_1$'s.

## Tolerance to Environmental Stress

Heat tolerance studies of *andigena* selections were continued under contract research at Cornell University. Plants were subjected to temperatures of 40° C during an 18-hour photoperiod and 35° C during the night, commencing 20 days after planting and continuing for three months. Although tuber yields were generally low, the testing procedure was in general agreement with previous classification of clones by greenhouse screening. The performance of single-leaf cuttings taken during the growing period was again successfully correlated with the performance of whole plants.

No relationship has been found so far between heat tolerance and the capacity to photosynthesize at high temperatures. Similarly, no relationship was determined between tolerance and susceptibility to high temperature damage of leaf membranes, as reflected by ion leakage from leaf discs. However, leaves of heat sensitive clones had higher dark respiration, especially at 40° C, than did comparable leaves of heat tolerant clones. The degree of cyanide stimulated dark respiration did not seem associated with differences in heat tolerance.

Five sources of germ plasm material are being used in developing populations adapted to the lowland tropics with adequate yield and disease resistance. These sources are: a) *tuberosum* germ plasm bred in northern latitudes from *andigena* clones introduced into Europe in the 16th century; b) neo-tuberosum germ plasm from an *andigena* population recently selected for tolerance to longer days and higher temperatures; c) *phureja-stenotomum* diploid material with a relatively high frequency of "2n" pollen which permits direct transfer at the tetraploid level; and, d) other sources of germ plasm such as *S. sparsipilum*, *S. chacoense*, *S. bulbocastanum* and *S. berthaultii* with high levels of pest resistance.

About 50,000 genotypes from these introduced and native diploid and tetraploid clones, as well as their hybrids, have been tested for adaptation to the lowland tropics. The highest and most stable yields corresponded to hybrids of the group *(tuberosum* x *phureja)* x *tuberosum*. The *tuberosum* x neo-tuberosum hybrids showed a specific adaptation to hot and humid conditions, while the *tuberosum* x *andigena* and neo-tuberosum x neo-tuberosum were unstable and unpredictable in their yield (Table 4).

**Table 4 — Yields of representative clones under the high and low jungle conditions at San Ramon (800 m) and Yurimaguas (180 m)**

| Clone | Germ plasm group | Yield (t/ha) | |
|---|---|---|---|
| | | San Ramon (90 days) | Yurimaguas (60 days) |
| N565.1 | tbr x neo-tbr | 47.5 | 16.5 |
| N570.5 | tbr x neo-tbr | 37.2 | 4.6 * |
| N574.1 | tbr x neo-tbr | 46.5 | 6.9 * |
| DTO-2 | tbr x (tbr x phu) | 38.9 | 9.5 |
| DTO-28 | tbr x (tbr x phu) | 44.8 | 17.4 |
| DTO-33 | tbr x (tbr x phu) | 38.2 | 12.5 |
| N503.152 | (neo-tbr x neo-tbr) | 35.3 | 3.9 |
| N513.3 | (neo-tbr x neo-tbr) | 33.6 | 2.3 |
| N545.3 | (neo-tbr x neo-tbr) | 37.2 | 4.6 |
| Mariva | (tbr x adg) | 15.1 | 0.3 |
| Revolucion | (tbr x adg) | 13.2 | 2.6 |
| Arran Pilot | (tbr x tbr) | 20.7 | 4.9 |
| Inti Sipa | (adg x adg) | 11.8 | 0.06 |

* Immature when harvested.

Frost commonly occurs during the growing season in highland potato growing areas in the tropics and subtropics. Breeding for frost tolerance has included laboratory-scale techniques permitting rapid screening. These screening techniques have been devised in cooperation with contract research at the University of Minnesota.

During four years, 175 clones tolerant to -4° C have been selected in the field from 890 of 38,670 seedlings originally screened in the laboratory. During this period 600 seedling families representing 21 species of tuber-bearing solanums have been evaluated. A total of 16,530 seeds of 128 families have been distributed for testing in eight developing country programs. Testing has been carried out at Usibamba (3,700 m) in Peru and at the Belen Experimental Station (3,900 m) in Bolivia; winter tests have been conducted at Atizapan (2,650 m) in the Toluca Valley, Mexico.

There is a low correlation between yield and frost resistance in the foliage at temperatures between 0 and -4° C. However, to obtain acceptable yields no more than 30 percent foliage damage can be tolerated. An increase in frost tolerance has been observed after intercrossing parents having only moderate frost resistance. Table 5 gives a summary of yields and degrees of resistance in several groups of hybrids as compared to the resistant species *curtilobum* and to the susceptible species *tuberosum*.

Table 5 — **Mean yield and foliage reaction obtained in *Solanum* hybrids following exposure to field frost of -4° C, Usibamba, Peru**

| Crosses * | Clones Selected/tested | Yield gms/plant | Frost damage 1-9 scale |
|---|---|---|---|
| (tbr x acl) x tbr x adg x adg | 22/56 | 900 | 2.8 |
| adg x (blv x phu) | 15/18 | 850 | 2.6 |
| (tbr x adg) x adg | 25/94 | 790 | 2.1 |
| adg x phu | 2/5 | 750 | 2.5 |
| adg x stn | 3/15 | 740 | 1.3 |
| cur x tbr | 7/26 | 740 | 2.3 |
| ajh x stn | 8/16 | 710 | 1.6 |
| cur x adg | 16/50 | 700 | 2.1 |
| adg x adg | 15/34 | 630 | 3.1 |
| phu x stn | 8/25 | 630 | 2.5 |
| cur (resistant control) | 7/23 | 580 | 1.0 |
| tbr (low resistance) | 7/9 | 340 | 5.1 |

* adg = *S. tuberosum* spp. *andigena* (2n = 48); acl = *S. acaule* (2n = 72)
ajh = *S. ajanhuiri* (2n = 24); blv = *S. boliviense* (2n = 24)
cur = *S. curtilobum* (2n = 60); phu = *S. phureja* (2n = 24)
stn = *S. stenotomum* (2n = 24); tbr = *S. tuberosum* (2n = 48)

**A strategy of population breeding for ecological adaptation has been developed based on the concept that the commercial value of a clone (X) may be expressed as the function:**

$$X = A + Y + R$$

where "A", "Y", and "R" represent the effects of groups of genes for adaptation, yield and disease resistance. "Y" genes would be related to the efficiency of a plant to use light energy and to transform it into plant material. Data presented in Table 6 illustrates the concept of the action of "Y" genes as influenced by "A" genes associated with adaptation to daylength.

**Table 6 – Mean foliage, tuber and total plant weights (gms) and tuberization efficiency (tuber weight/plant weight) of genotypes from two taxonomic groups growing under three daylengths**

| Group | Daylength hours | Weight (gms) | | | Tuberization efficiency |
|---|---|---|---|---|---|
| | | Plant | Tuber | Total | |
| *phureja* | 11 | 142 | 199 | 341 | 1.39 |
| | 13 | 274 | 103 | 377 | .41 |
| | 15 | 283 | 95 | 378 | .33 |
| *tuberosum* | 11 | 176 | 470 | 646 | 2.66 |
| | 13 | 231 | 485 | 716 | 2.10 |
| | 15 | 272 | 498 | 770 | 1.83 |

The total weight of plant material in the short-day adapted *phureja* was nearly the same under the three daylength regimes; tuberization efficiency was markedly reduced under 13 and 15-hour photoperiods. Thus the inherent capacity of *phureja* genes to transform light energy into chemical energy was not changed, but the possibility for the distribution of the photosynthates was altered as no or few tubers were initiated at longer daylengths.

The yield, total plant weight and tuberization efficiency of the *tuberosum* material was higher than *phureja*, indicative of long-term selection of genes for yield. For *tuberosum* there was an eight-day delay in tuberization when daylength was increased from 11 to 15 hours. However, the brief delay enhanced foliage growth. The genes for adaptation maintained regulatory action and the genotype was able to overcome a developmental lag in tuberization to give an apparent increase in final yield.

Improved hybrids involving the taxonomic groups *tuberosum*, neo-tuberosum and *phureja* have yielded about one kg per plant in growing periods of 60 to 70 days. Materials of similar genetic constitution have been distributed to Sri Lanka, the Philippines, Costa Rica, Brazil, Ecuador, Pakistan, Turkey, Brunei and Tahiti.

In addition to breeding for resistance to environmental stress, it is feasible in the future to also breed for disease and pest resistance. Thus, combined resistance to late blight and cyst nematodes might be coupled with frost resistance. Or, bacterial wilt and root-knot nematode resistance might logically be associated with clones having adaptation to a hot, humid environment. Various combinations of two or three factors are being considered in response to production risks under specific ecological conditions.

Laboratory, storage and greenhouse facilities at CIP's Santa Ana experiment station in the Mantaro Valley near Huancayo.

## CONTROL OF IMPORTANT FUNGAL DISEASES OF POTATOES

In 1977 a booklet was prepared by CIP staff to assist field workers in the identification of some of the major potato diseases; 16 fungal diseases of varying worldwide importance were included. Research at CIP during the year was concentrated on four of these diseases: late blight *(Phytophthora infestans)*; wart *(Synchytrium endobioticum)*; stem canker *(Rhizoctonia solani)*; and, smut *(Angiosorus = Thecaphora solani)*. Field observations were made on diseases caused by *Choanephora* spp., *Macrophomina phaseoli*, *Phoma exigua*, *Alternaria solani* and *Phytophthora erythroseptica*.

### Late Blight

Throughout 1977 seedlings were screened for resistance to *P. infestans* in a standard environment favorable for late blight development. During the year 12,556 seedlings (29 percent) were selected from 42,909 seedlings belonging to 425 families which were screened for late blight resistance. Survivors from seedling screening trials were then tested under field conditions.

It is important to emphasize that CIP breeding for late blight resistance is concerned only with field or general resistance. However, at present there appears to be no simple field method to separate, in all cases, general or field resistance from specific or "major gene" resistance. This major gene resistance was observed at Toluca, Mexico where the perfect stage of *P. infestans* is present. Possibly because of the scarcity of "compatible" hosts, the frequency of races able to overcome the resistance of the "higher" R-genes, e.g. $R_5$, $R_7$, $R_8$, $R_9$, $R_{10}$, $R_{11}$, is relatively low. Commonly, these are complex races able to attach some or all of the 10 single R-gene differentials available. Thus, what appears to be field resistance in some clones is in fact the result of the delayed appearance of an appropriate virulent and aggressive race. This is illustrated in Fig. 2 in which the development of $R_1$ races is contrasted with the development of $R_{10}$ races, in triplicate plots having varying numbers of plants compatible with either $R_1$ or $R_{10}$ races. $R_1$ races occurred generally in the experimental area.

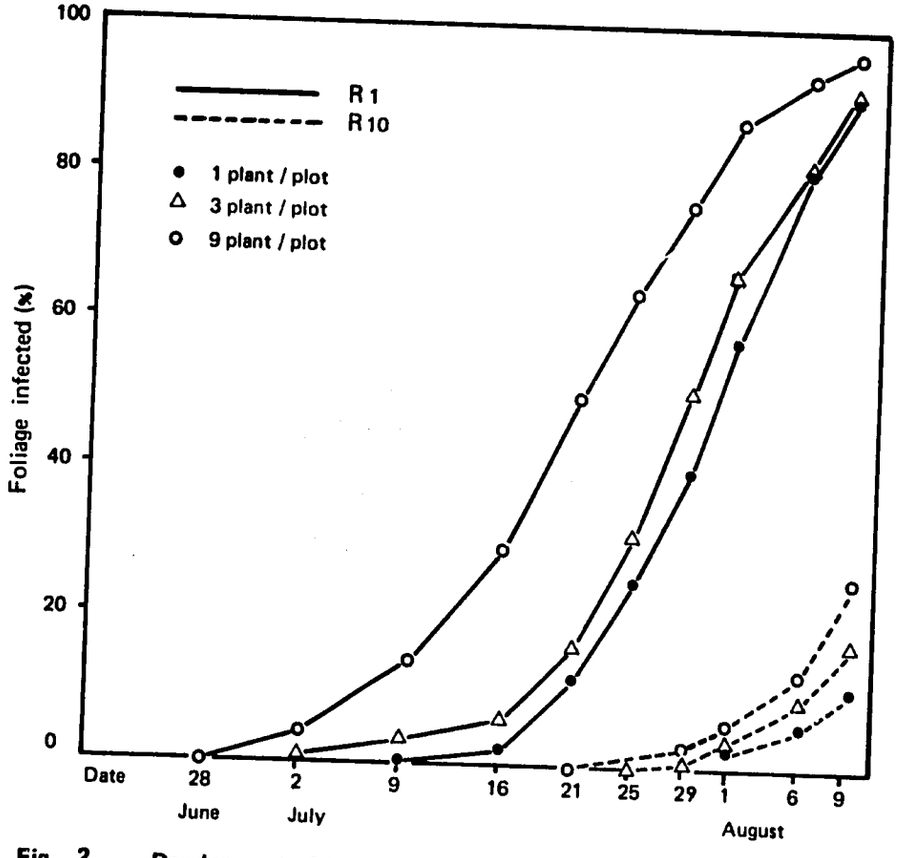



**Fig. 2 — Development of late blight on $R_1$ and $R_{10}$ differential hosts in plots having one, three and nine plants.**

Seven institutions, including three in the Netherlands and one each in India, Sweden, USA and West Germany, participated in the International Late Blight Trials in Mexico. A total of 1,048 clones were tested in 1977. Materials previously selected for blight resistance in 1976 were planted in Costa Rica to evaluate bacterial wilt resistance. Only 11 of 207 clones survived to harvest because of severe bacterial wilt attack. (Three clones, India IIII, N-503-262 and Cruza 148 had *Pseudomonas* resistance and good adaptation.)

The late blight population in Llano Grande, at 2,300 m in the province of Cartago, Costa Rica, was found to overcome the resistance of at least eight out of nine single R-gene differentials (Table 7). (Note: Differential $R_5$ remained highly resistant throughout the season; $R_1$ $R_3$ differential was susceptible, indicative of the presence of a race 3.)

**Symptoms of late blight caused by *Phytophthora infestans*, on leaves, stem and tubers of potato.**

*T is and the following color illustrations are taken from :*

*i e International Potato Center . 1977 . The potato ; major diseases a d nematodes . Centro Internacional de la Papa , Lima , Perú .*

**Table 7 — Appearance of *Phytophthora infestans* on differentials during 197 at Llano Grande, Costa Rica. Late blight was rated on a 1-9 scale**

| Differentials | June | | | July | | | | | August | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 17 | 24 | 1 | 8 | 15 | 22 | 29 | 5 | 12 |
| $R_1$ | 1 | 2 | 4 | 6 | 6 | 7 | 7 | 7 | 9 | 9 |
| $R_2$ | 1 | 1 | 5 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| $R_1R_2$ | 2 | 2 | 5 | 7 | 7 | 7 | 8 | 9 | 9 | 9 |
| $R_1R_3$ | 2 | 2 | 2 | 4 | 4 | 6 | 6 | 7 | 9 | 9 |
| $R_1R_2R_3$ | 1 | 2 | 2 | 4 | 4 | 5 | 7 | 7 | 9 | 9 |
| $R_4$ | 2 | 2 | 5 | 6 | 6 | 7 | 8 | 8 | 8 | 9 |
| $R_1R_4$ | 1 | 2 | 4 | 7 | 7 | 8 | 9 | 9 | 9 | 9 |
| $R_2R_4$ | 1 | 2 | 4 | 8 | 8 | 9 | 9 | 9 | 9 | 9 |
| $R_5$ | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| $R_7$ | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 4 | 7 |
| $R_8$ | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 5 |
| $R_{10}$ | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 5 | 7 |
| $R_{11}$ | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 5 | 9 |

A comparison was made between two methods of evaluating late blight incidence at San Ramon, Peru, by: 1) estimating the percentage of foliage affected, transformed to logit units; and, 2) by scoring blight incidence on a 1-9 scale. On the basis of the regression of disease development with time for both methods, a high correlation, $r^2 = 0.95$ and 0.97, respectively, was found. There was also a good correlation, $r^2 = 0.78$, between the two types of apparent infection rate (Fig. 3). A correlation, $r^2 = 0.67$ (Fig. 4), was found in comparing components of blight resistance in the field and in controlled growth chamber studies.

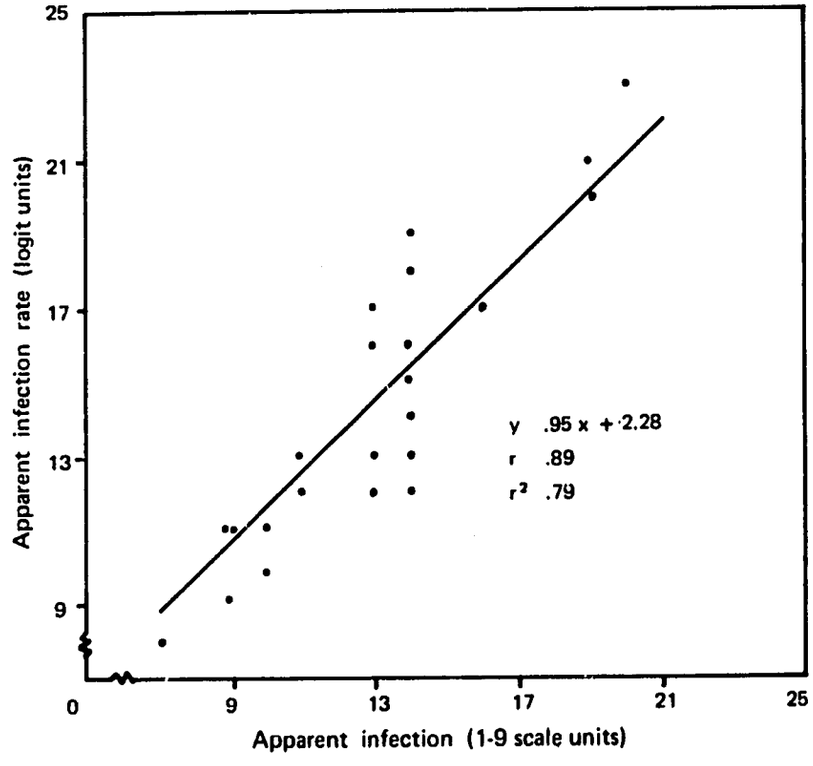



**Fig. 3 — Correlation between apparent infection rates in logit units and blight incidence scored on a 1-9 scale.**

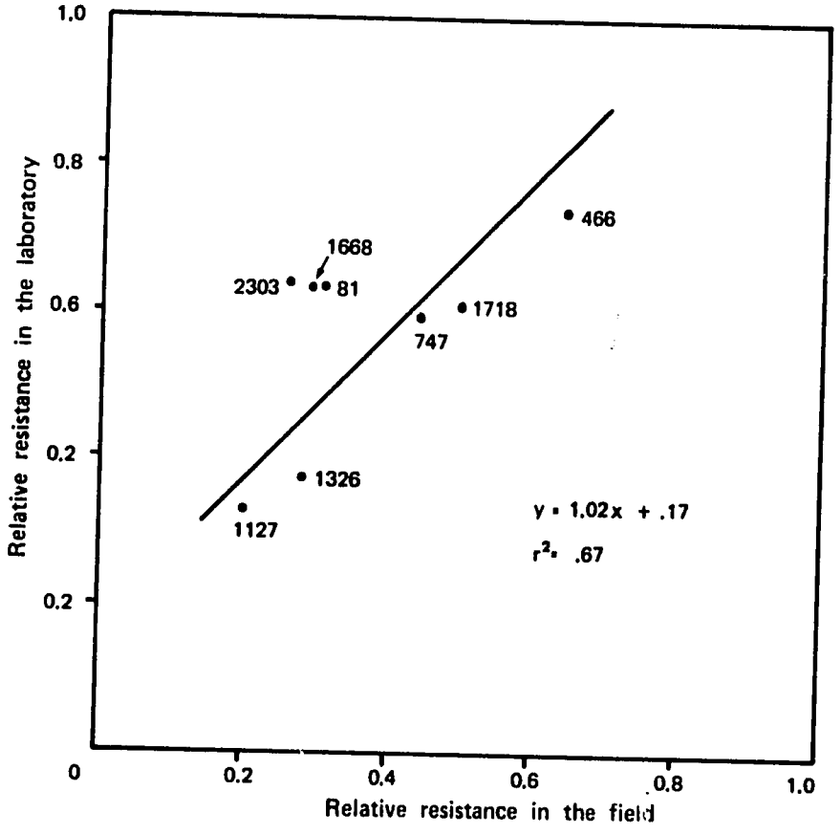



**Fig. 4 — Comparison between field and laboratory results expressed as relative resistance: 1 — susceptible test plant/susceptible variety, Revolucion. (Accessions # 2303, 1668 and 81 lodged under field conditions at San Ramon.)**

In other field studies at San Ramon, a high jungle area, 150 clones were selected for late blight resistance from an original 4,000 clones of *Solanum phureja* and derivatives; 47 of 264 clones of separate origin were also selected in blight resistance and yield trials as part of a continuing field assessment program. It is of interest that of 13 isolates of *P. infestans* collected at San Ramon, 11 belonged to race "0", one to race "1" and one to race "4.10". This limited spectrum of races is in contrast with observations at Llano Grande, Costa Rica where many differentials were susceptible. No difference in rate of growth at 20° C was found in studies of possible "environmental races" collected from an irrigated sea level desert area, from high jungle sites (800 m) or from alpine fields (3,000 + m). Inoculation of progenies derived from selfed India 952 and India 800, with five different concentrations (4,000 to 45,000/ml) of zoospores (race 1.4), showed no significant increase in seedling infection with increase in the number of zoospores. The results are not in accordance with expectations on the basis of polygenic heritability of partial or field resistance.

In contract research at the Swedish Seed Association station in Svalov, Sweden, the inheritance of components of leaf resistance to late blight were observed in three different materials:

a) Selfed clones of *S. andigenum* and *S. phureja* were tested for resistance to entrance and resistance to invasion in the absence of "R" genes. Moderate levels of resistance to entrance and invasion were found. The variation among seedlings within populations was significant regarding both resistance to entrance and resistance to invasion, while among populations only resistance to entrance was significant. No significant differences were found between *andigenum* and *phureja* species.

b) Resistance to entrance, invasion and degree of attack after a 24-hour inoculation access period were measured in a total of 3,000 seedlings from 17 populations. At least one parent was known to have a fairly high level of non-specific resistance derived from *S. demissum*, in most cases after seven to nine backcrosses with *S. tuberosum*. Resistance to invasion was related to the parent clones varying from e.g., 9.06 (Eigenheimer) to 1.43 (resistant Svalov parent). Betweeh six and 58 percent of seedlings in different populations were not attacked by *P. infestans* after

a 24-hour inoculation access period. Because seedling resistance varied, being higher or lower than midparent values in some populations, it is evident that progeny testing in potato breeding is important. The existence of dominance or epistatic effects and a special uniting ability in some combinations of genotypes is indicated.

c) Seedlings from diallel crosses between parents with different levels of non-specific resistance were being evaluated at year end.

Late blight trials were carried out at Nigale, Nepal, in 1977 in cooperation with the National Potato Program. All the tested clones, including the late blight susceptible clone 80050, performed significantly better and had higher yields than local checks. Compared with the local yield (8-15 t/ha), the most successful among the clones tested had yields of 40-50 t/ha, as extrapolated from field plot data of 70 clones and varieties. Based on late blight resistance the following clones were ranked: 1 - 750815, 2 - 676004, 3 - 575012, 4 - 575015, and, 5 - 676003. There were no significant yield differences among these clones.

**Wart**

The search for resistance to *Synchytrium endobioticum*, the causal agent of wart, was initiated in 1968 in Peru, and was incorporated as a CIP project in 1972. During the 1970-71 growing season, 52 of a total of 500 clones were selected for resistance. In 1972-73 these were retested in the field at Casablanca, as well as in plots in which inoculum from Casablanca and Cuzco was used. An additional 500 clones were also screened during the same period. From this initial research, highly resistant clones were selected by exposure to three field populations of *Synchytrium*.

Although possessing a high degree of resistance, most of the clones were low yielding and of poor commercial quality. A breeding program initiated in 1974-75 was aimed at the utilization of wart resistant material to develop lines with good yield, quality, and in some instances, incorporating resistance to cyst nematodes, *Globodera rostochiensis*. Seedling screening techniques were evaluated and an efficient method selected to screen the large number of seedlings arising from the breeding program.

During 1975-1977, from the many hundreds of seedlings screened for combined wart, cyst nematode and yield characteristics, 1,374 seedlings are being used for further evaluation. Of interest has been the initial failure of European differential varieties to provide effective identification of races of *S. endobioticum* in Peru. Only Ackersegen and Urgenta were resistant while the other differentials: Deodara, Blanik, Nova, Gievont, Fortuna, Ultimus, Fontana, Saphir, Apollo and Ora, were all susceptible against an isolate of *Synchytrium* from Casablanca, Peru. This response indicates the presence of races different than those determined in Europe.

Wart is a serious disease in several areas of eastern Nepal. The prevailing race appears to be race 1. A number of clones provided by CIP to the National Potato Program were tested in the field at Rolekhani during 1977 and found to be resistant to both wart and late blight. Some of these clones also have been tested at Wageningen, the Netherlands. Clones (CIP numbers) 720047, 676003, 575010, 575008 and 575031 were selected in Nepal as potential varieties for further evaluation in commercial adoption.

**Stem Canker**

*Rhizoctonia solani*, the causal agent of stem canker and black scurf disease, is present in nearly all soils where potatoes have been grown. The severity of the disease is commonly influenced by the local soil environment. While CIP is not involved in either screening or breeding for rhizoctonia resistance, the disease was significant in some fields where CIP test plots were planted during the year. Losses have been observed of potato seedlings in excess of 50 percent within two weeks of transplanting to the field.

Various fungicide formulations and methods of application have been evaluated in the control of stem canker. The best protection, in response to this special problem, was to spray seedlings with 0.2 percent of the systemic fungicide "Benlate" several days before transplanting to the field. This treatment may be repeated 15 days after transplanting as an added precaution.

Benlate treated and control plants of the variety "Renacimiento" grown in soil infected with *Rhizoctonia solani*.

## Smut

Smut, caused by *Angiosorus* (= *Thecaphora*)*solani*, is a tuber disease found in several Central and South American countries. At maturity, diseased tubers may disintegrate rapidly into masses of brown spores. Continuing field observations of this disease are being conducted. Losses up to 80 percent under commercial growing conditions have resulted.

In 1977, 66 of 6,444 clones in the germ plasm collection in the Mantaro Valley, Peru, were affected by smut; 16 of those clones were also attacked in 1976. Smut is rather capricious in its appearance so that field screening for resistance or fungicide tests in CIP experimental fields is of limited value. While a close watch is being kept on the distribution of the disease in new experimental fields, greenhouse experiments have been initiated to screen fungicides. A number of Peruvian potato varieties have resistance to smut.

## Other Fungal Pathogens

Several site-specific fungal pathogens with varying seasonal severity continue to be observed as a matter of record.

*Alternaria solani*, the causal fungus of early blight, was relatively severe in San Ramon experimental plots during 1976 and 1977. Considerable differences in resistance to early blight were recorded in late blight resistant clones.

The main fungal pathogen at the San Ramon site was *Sclerotium rolfsii* which attacked potatoes in all stages of development. The incidence of basal stem rot was especially severe in plots where potato or peanut residues were incorporated. Up to 80 percent of plants did not emerge.

Under very hot, humid conditions in the lowland jungle area near Yurimaguas, Peru, Choanephora blight is a common disease of beans, cowpea and soybeans during the rainy season. The species most frequently isolated was *Choanephora cucurbitarum* followed by *C. conjuncta* and *C. circinans*. Only isolates of *C. cucurbitarum* have been found to cause widespread foliage damage in potatoes following a period of dry weather. A *Diaporthe* also has been repeatedly observed to incite a wet, slimy rot of soybean, cowpea and potato.

Isolates of *Phoma* have been obtained in Ancash, Cajamarca, Huancayo and Puno in the Peruvian highlands. Most of the isolates have been identified as forms of *P. exigua* which differ in their capacity to form small lesions on leaves and extensive rot of potato tubers. *Phoma* isolated from *Chenopodium quinoa* and potato in the Puno area of Peru during the 1977 growing season, were found to be highly pathogenic to potato tubers.

The pink rot fungus, *Phytophthora erythroseptica*, caused losses in germ plasm material and seed multiplication plots at Huancayo. In 1977, 762 of 6,444 clones examined were affected. Diploid material was particularly susceptible with losses of over 70 percent, depending upon the relative susceptibility of clones. Treatment of field plots with Basamid, 300 kg/ha, has resulted in substantial yield increases.

## CONTROL OF IMPORTANT BACTERIAL DISEASES OF POTATOES

Emphasis during 1977 continued to be placed on bacterial wilt of potatoes caused by *Pseudomonas solanacearum*. Bacterial wilt, also known as brown rot, is the most serious bacterial disease of potatoes in the tropical and subtropical regions of the world where it may limit production. Pathogenic strains of *P. solanacearum* attack a number of different crops. Races 1 and 3 are pathogenic on potato.

In screening for resistance to bacterial wilt it is important to expose potatoes to as wide a range as possible of pathogenic biovars of races 1 and 3. A collection of more than 90 isolates of *P. solanacearum* has been assembled by CIP, two-thirds from potato, the remainder from other crops. Forty-eight of these isolates from the Americas have now been identified to race. Among 40 isolates from potato, 31 were race 3 and nine were race 1. Of the remaining eight isolates, six from tomato and one each from ginger and chili pepper were race 1. All 48 isolates were pathogenic on susceptible potato clones.

It has been considered that race 1 of *P. solanacearum* originated in the lowland tropics and race 3 in the highland tropics. The latter race affects only potatoes. However, both race 1 (biovar I) and race 3 (biovar II) have been isolated recently from wilted potatoes grown on newly cleared jungle land in Yurimaguas, Peru, in the Amazon basin. The presence in virgin jungle of both races which are capable of wilting potatoes, indicates the continuing need to breed for resistance to *P. solancearum*. It also raises a question about the assumed highland origin of the low temperature race.

The collection of *Pseudomonas* isolates is valuable in verifying the breadth of resistance to infection of a potato species or clone. For example, the response of *Solanum sparsipilum* to isolate 013 of race 3 suggests immunity (See Table 8). But in a preliminary study of the resistance of *S. sparsipilum*, as well as *S. chacoense* and the Peruvian variety "Mariva" *(S. tuberosum* x S. tbr spp. *andigena)*, to a range of bacterial isolates, it is evident that variation was present, in host susceptibility to bacterial biovars (Table 9).

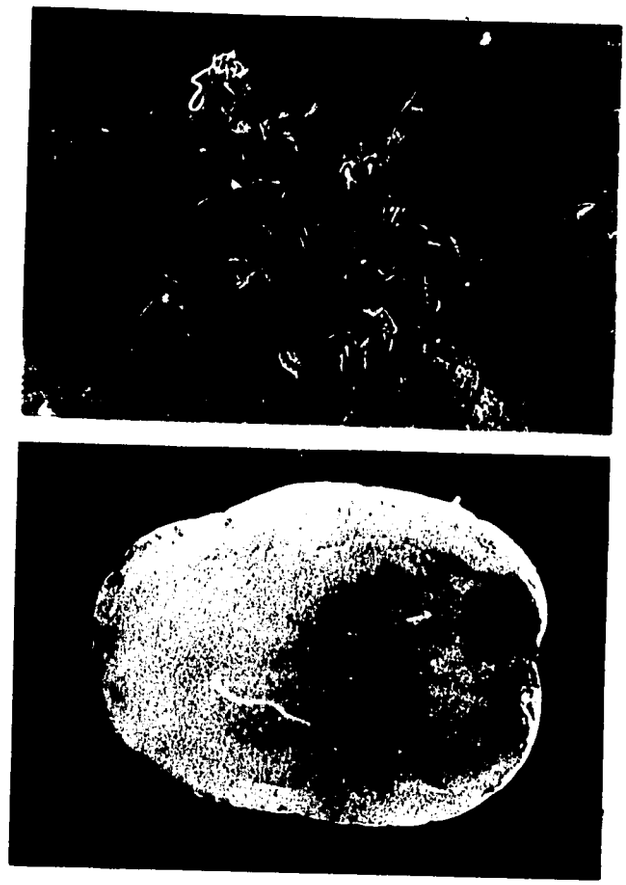
**Table 8 – Susceptibility of *Solanum sparsipilum*, *S. chacoense* and cultivar "Mariva" to 12 different isolates of *Pseudomonas solanacearum* (average 10-13 plants) ***

| Isolate no.. | Race no. | Biovar | Percent wilted plants | | |
|---|---|---|---|---|---|
| | | | "Mariva" | *S. sparsipilum* (CIP 760147.7) | *S. chacoense* (CIP 760917.1) |
| 041 | 3 | II | 50 | 0 | 8 |
| 048 | 3 | II | 60 | 15 | 69 |
| 068 | 3 | II | 80 | 8 | 38 |
| 075 | 3 | II | 60 | 46 | 54 |
| 095 | 3 | II | 50 | 0 | 46 |
| 096 | 3 | II | 50 | 23 | 38 |
| 018 | 1 | I | 80 | 0 | 30 |
| 040 | 1 | IV | 40 | 0 | 0 |
| 045 | 1 | I | 60 | 0 | 46 |
| 047 | 1 | I | 70 | 15 | 23 |
| 052 | 1 | III | 60 | 0 | 61 |
| 072 | 1 | I | 60 | 8 | 0 |

* In preliminary screening for resistance of wild *Solanum* species, plants are normally exposed to an aggressive isolate of the common potato race 3.

**Table 9 – Wild *Solanum* species screened for resistance to *Pseudomonas solanacearum* (Peruvian isolate 013, race 3)**

| Solanum species | Accession no. | Plants wilted/tested |
|---|---|---|
| *S. brachistotrichum* | P.1 283095 | 10/10 |
| *S. brachycarpum* | P.1 275180 | 9/11 |
| *S. hjertingii* | P.1 186559 | 5/7 |
| *S. huancabambense* | ZH 966 | 0/4 |
| *S. lesteri* | HHh 1714 | 4/6 |
| *S. lignicaule* | P.1 310993 | 4/5 |
| *S. sogarandium* | P.1 230510 | 1/3 |
| *S. sucrense* | HHC 4541 | 3/8 |
| *S. sucrense* | HHC 4580 | 4/8 |
| *S. sucrense* | HHC 4615 | 8/10 |
| *S. weberbaueri* | P.1 265880 | 3/6 |



**Haulm and tuber symptoms of bacterial wilt caused by *Pseudomonas solanacearum*.**

From a previous screening of 65 accessions for 33 species, three accessions of *S. demissum* and two of *S. jamesii* are being increased for further testing against different isolates of *P. solanacearum*.

Substantial evidence has been accumulated of the increased incidence of bacterial wilt in the presence of the root-knot nematode, *Meloidogyne incognita*. In continuing studies, the resistance of *S. sparsipilum* is being observed with respect to the deterioration of wilt resistance in the presence of root-knot nematodes.

The survival of *P. solanacearum* from potato crop to potato crop is influenced by the soil environment and presence of other susceptible hosts. As reported previously, in wide scale screening of common crop and weed hosts, only the tomato variety "Marigold", *Nicotiana glutinosa* and the weed, *Solanum nigrum* were susceptible to a range of isolates of *P. solanacearum*, races 1 and 3.

Recently, in contract research in Costa Rica it has been observed that bacterial populations decreased rapidly after the harvest of potato. This occurred both in Alajuela, at 800 m on the wet-dry Pacific slope, and in Turrialba at 660 m on the wet Atlantic slope. At both locations potatoes were severely infected by soil borne inoculum; over 50 percent of the plants wilted in the field and more than 40 percent of healthy appearing tubers rotted in storage.

Field screening for resistance to bacterial wilt has been discontinued in CIP plots at La Molina, due to the failure to sustain sufficiently high populations of bacteria for satisfactory resistance assay. Field research has been transferred to Huanuco at 2,300 m, where bacterial wilt is an endemic problem. The failure of the disease to persist in such locations as the coastal plain of Sri Lanka, certain areas in Kenya, as well as at the Viru and La Molina sites in Peru, suggests a need to evaluate the influence of diverse soil environments on bacterial survival. "Molinera", a new bacterial wilt and late blight resistant clone, has been released recently by the Peruvian National Potato Program. This variety is the original clone BR 63.65 from the University of Wisconsin/CIP joint program. In Nigeria trials are continuing with material developed through earlier Wisconsin/CIP associations. Clone BR 63.5, during five year field trials at Vorn in the Jos plateau, has consistently displayed relatively high yields.

Contract research at the University of Wisconsin has two main objectives: 1) the development of potato clones with combined resistance to bacterial wilt, late blight and virus Y; and, 2) the isolation and purification of potato lectin and the production of antisera to lectin, as part of studies of the basic mechanisms of resistance to *P. pseudomonas.*

Approximately 470 clones selected through a greenhouse screening program for bacterial wilt resistance, were sent to Toluca, Mexico for field testing against late blight in the International Late Blight Testing Program. Of these clones, 185 had survived both bacterial wilt and PVY screening procedures. Under severe late blight conditions at Toluca, 41 clones were selected for blight resistance. The most promising clones with combined resistances are being increased in Mexico for distribution to growers in areas where bacterial wilt has become severe.

During 1977 standard screening procedures were continued in Wisconsin to provide additional clones for 1978 testing in Costa Rica and Colombia. Of 1,488 seedlings belonging to 21 families, 484 survived screening for PVY. Of particular interest was the very high proportion of progenies from crosses involving "Mirka", "Saphir" and "Annet" that had resistance to PVY.

**Nature of Wilt Resistance**

During the past year, research at the University of Wisconsin has emphasized the further study of pathogen and host factors involved in "recognition" of virulent and avirulent strains of *P. solanacearum* by potato leaf cells. Based on previous research, it has been hypothesized that lipopolysaccharide (LPS) constituents of the bacterial cell wall are specifically bound by a lectin on the host cell wall. Virulent bacteria produce an extracellular polysaccharide (EPS) that apparently prevents binding. Thus, virulent cells are free to multiply in the intercellular fluids.

Recently emphasis has been placed on developing methods to study the kinetics of lectin, EPS, LPS interactions. It was found that nitrocellulose filter membranes bind potato lectins very tightly, yet the lectin appears capable of binding to sugars that contain internal N-acetyl glucosamine groups. Binding of $^{14}C$-EPS to lectin is inhibited by "cold" EPS, suggesting a competitive interaction. Even though

LPS has no affinity for EPS, at appropriate concentrations it can completely inhibit binding of EPS to the lectin. However, competition studies have shown that EPS has higher specificity for binding sites on the lectin and that it displaces LPS. These results support the hyphothesis that EPS is an effective inhibitor of bacterial attachment to cell walls because it has greater affinity than LPS for the binding site on the lectin.

Antisera to potato lectin has been obtained by injection of purified preparations into New Zealand rabbits. An antiserum specific for the lectin is being used in an effort to locate lectin in potato tissues. Also this antiserum should prevent the hypersensitive reaction if lectins bind virulent B-1 type *P. solanacearum* cells before the reaction is induced.

Efforts have been made to establish the relationship between the agglutinating properties of lectins extracted from different potato clones and the resistance of these clones to bacterial wilt. This involves the extraction of lectins from each clone, their purification and assay against a wide range of isolates of *P. solanacearum*. Lectins were purified from six bacterial wilt resistant clones and tested against five strains of the pathogen representing a wide spectrum of races and biotypes. In general the most resistant clones produced lectins able to agglutinate all "fluidal" strains of the bacterium.

# CONTROL OF IMPORTANT VIRUS DISEASES OF POTATOES

During November, 1977, a planning conference on "Developments in the Control of Potato Viruses" was sponsored by CIP. An international group of virologists, during a week of meetings, reviewed the Center's virus research program. The following synoptic assignment of priorities was expanded into detailed recommendations to serve as guidelines for a 5-year CIP virus research program (Table 10).

**Table 10 — Assignment of priorities in CIP's virus control program**

| Viruses * | Breeding | Testing | Research |
|---|---|---|---|
| PLRV | 1 | 1 | 1 |
| PVY - PVA | 2 | 4 | 3 |
| PVX | 3 | 5 | 5 |
| PSTV | 4 | 2 | 2 |
| New Viruses | 5 | 3 | 4 |

* PLRV = Potato leaf roll virus; PVA, PVX, PVY = Potato viruses "A", "X" and "Y", respectively; PSTV = Potato Spindle Tuber Viroid.

## PLRV

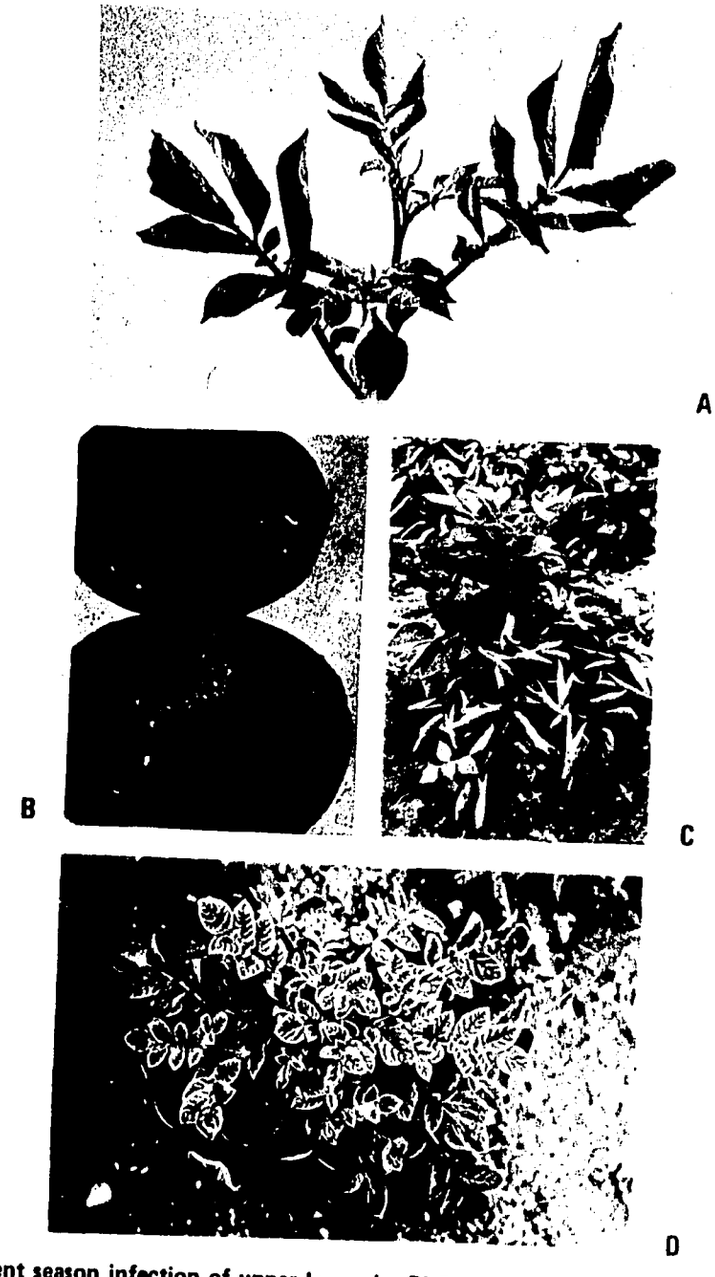
Potato leaf roll virus (PLRV) is CIP's first priority in breeding and testing for resistance to viruses. Work continued with two potato populations established last year for the development of infection resistance through phenotypic recurrent selection, one tetraploid and one diploid. The material containing PLRV resistance was taken from several sources: true seed of diploid and tetraploid crosses from Germany, as

well as, tetraploid material from England, Canada and the Netherlands; and, breeding lines and cultivars with high levels of resistance from selection programs in eight different countries in North and South America and Europe. The other major souces of crosses for the two

populations were the CIP germ plasm collection and neo-tuberosum material from Cornell University with resistance to PVY + PVA and to PVX. These latter sources were incorporated into the tetraploid population.

The material grown under long-day conditions in northern regions flowered poorly under short-day conditions in Peru, reducing the material's direct usefulness in breeding. A notable feature of the groups of resistant breeding lines and cultivars received from Scotland, Canada and Germany was that a proportion of each group developed strong secondary leaf roll symptoms when grown under CIP conditions. The possibility exists that these suscepts were infected with strains of the virus which do not reveal symptoms under conditions of origin.

Screening for resistance to PLRV in clonal material is being conducted by exposing rooted cuttings to infective aphids in the greenhouse, as previously described (page 36, CIP Annual Report, 1976). The cuttings are then transplanted to the field and observed for symptom development. Secondary symptoms develop directly. Table 11 gives the results of a trial in which cuttings of six Peruvian cultivars were tested. It is of interest that when single tubers from each of the evidently healthy Ccompis plants were replanted, 23 percent showed typical secondary symptoms. The necessity of confirming resistance by planting tubers from evidently healthy cuttings is apparent.




A) Current season infection of upper leaves by PLRV; B) Net necrosis of tubers of a sensitive variety; C) Secondary symptoms in a plant grown from a PLRV infected tuber; and, D) Marginal and interveinal chlorosis of an *andigena* plant secondarily infected with PLRV

Table 11 — **Percent symptom expression in rooted cuttings exposed to PLRV before planting in the field**

| Cultivar | Percent with symptoms |
|---|---|
| Mariva | 24 |
| Ccompis | 25 |
| Revolucion | 64 |
| Mi Peru | 66 |
| Renacimiento | 92 |
| Merpata | 95 |

A further refinement of screening for PLRV resistance in seedlings avoids the necessity of transplanting to the field and consequent losses due to fungi. In large-scale tests, open-pollinated seed of cultivars were sown in rows in trays of replicated blocks. When seedlings were 1-3 cm high, PLRV-infective aphids were placed directly onto each seedling. Two weeks later an insecticide was applied to kill the aphids. Seedlings were then transplanted to "Jiffy" pots and symptom readings were taken periodically. Distinct seedling symptoms developed and consisted of an upright habit, chlorosis of upper leaves, rolling of lower leaves and/or purpling of leaf undersides (i.e. typical secondary symptoms).

In a preliminary trial, 30 of 33 seedlings of the susceptible variety "Renacimiento" developed symptoms, when only seven of 44 seedlings of the more resistant Ccompis had visible symptoms. The results of two further PLRV-seedling infection experiments are presented in Table 12. In Experiment 1, there were three replicate blocks with a total of 133-162 seedlings per cultivar; blocks were replicated four times in Experiment 2, with 82-234 seedlings per cultivar.

**Table 12 – Percent symptom expression in potato seedlings exposed to PLRV before transplanting to "Jiffy" pots**

| Cultivar | Percent with symptoms * | |
|---|---|---|
| | Experiment 1 | Experiment 2 |
| Hualash | 6 (12) | 11 (14) |
| Yana Imillia | 13 (26) | 16 (20) |
| Ccompis | 12 (23) | 17 (21) |
| Huagalina | – | 21 (26) |
| Casa Blanca | – | 22 (27) |
| Mi Peru | 39 (75) | 66 (82) |
| Merpata | 43 (83) | 78 (96) |
| Renacimiento | 52 (100) | 81 (100) |

* Percentage of seedlings with symptoms followed by percentage in parentheses equated to Renacimiento = 100 percent.

Studies are underway to improve the reproducibility of direct aphid infection of sprouts on tubers as a rapid method of screening clonal material. Included in these studies are more efficient techniques using complexes of chemicals to uniformly break dormancy. Small scale trials, using the resorcinol method for direct detection of PLRV in tubers, have not proven to be a useful alternative to making symptom readings in plants. Healthy tubers of some clones developed abundant, but apparently normal, levels of callose in the phloem.

New sources of resistance to PLRV continued to be monitored during 1977. For example, the native *andigena* cultivars (Table 12), including Hualash, Yana Imillia, Ccompis, Huagalina and Casa Bianca, appeared more resistant than Mi Peru, Merpata and Renacimiento. Infection resistance to PLRV of these five native cultivars may have played an important role in their survival as cultivars.

Failure of *Solanum brevidens* to develop PLRV symptoms has been observed in England over a period of many years under optimal conditions for spread of this virus. In trials at CIP, it was confirmed that *S. brevidens* (PI 218228) is highly resistant, but not immune, as a low level of virus can be detected in graft-inoculated plants. Similar resistance also appears to be present in *S. fernandezianum* (PI 320270) and *S. etuberosum* (PI 245924).

Clonal material consisting of breeding lines and cultivars with infection resistance to PLRV (and/or PVY) has been sent to 14 developing countries in six of seven CIP regions. Evaluation of seedlings from crosses for PLRV resistance continued at seven sites outside Peru, as previously described (page 36, CIP Annual Report, 1976).

In contract research at Cornell University high levels of resistance to PLRV have been reported in clones K349-7 and NY61, the latter from a cross made in 1969. The pedigree of NY61 includes selections from Peruvian and Colombian seed lots. In five years of testing, NY61 in 10 trials, produced 13 percent more tubers than "Katakdin" which were greater than 5 cm diameter.

## PVY

In Cornell University contract research, mechanical inoculation at the seedling stage proved to be a reliable means of PVY transmission of the common New York strain. Of 641 tub x tub clones tested, 170 were resistant and 196 were susceptible. This fits a ratio of 13:15, assuming random chromatid segregation and a single dominant gene conferring resistance.

Plants that were resistant to mechanical transmission were also resistant when inoculated by aphids. To determine the type of resistance, top-graft and approach-graft tests were made. Failure to recover the virus from inoculated resistant plants, by either grafting method, suggests that immunity is involved. The high level of resistance to PVY in *andigena* populations has resulted in a decision to incorporate this

resistance in all future *andigena* breeding cycles. In 1977 the Cornell PVY exposure plot consisted of 78 PVY resistant *andigena* clones from the sixth cycle planted in five-hill plots. Six showed typical PVY symptoms. Observations were also made on 660 two-hill plots of adg x tub and tub x adg hybrids which had resistant parents.

## PVX

Potato virus strain $X_{HB}$, originally from Bolivia, is of special interest because it infects *Gomphrena globosa* without producing local lesions. $X_{HB}$ also breaks the resistance of the gene for PVX immunity from

*S. acaule*. It is considered to belong to group two of Cockerkam's classification of PVX strains. At present studies are underway to challenge the immunity of USDA 41956 and of certain neo-tuberosum clones with $PVX_{HB}$.

## Novel Viruses

In studies with new or little known viruses, characterization of Andean Potato Mottle Virus (APMV), Andean Potato Latent Virus (APLV) and Potato Virus T (PVT), were continued during 1977. APMV, a comovirus, causes severe symptoms in potatoes whereas APLV and PVT are normally mild or latent. APLV can cause severe symptoms in sensitive cultivars growing in cold conditions at high altitudes.

Several new viruses of undefined importance were identified, two of which, 14R and Wild Potato Mosaic Virus (WPMV), were extensively studied. The physical characteristics of 14R particles, the host range, sap transmission and serological relationship to tobacco mosaic virus, were determined. WPMV, isolated from *Solanum chancayense* growing in the Peruvian coastal desert, is not considered to be of economic importance because of a restricted host range in *Solanum*. WPMV appears to be the first virus studied from naturally infected wild potatoes. It represents a third PVY-type potato virus, in addition to PVY and PVA.

The causal agent of the potato yellow vein disease (PYVV), which is a very common and important disease in Ecuador, was isolated for the first time by mechanical inoculation to *Datura stramonium*. The virus has been partially characterized. The advice of Dr. B.D. Harrison, Scottish Horticulture Research Institute, is gratefully acknowledged in studies of PYVV, APMV, T and 14R viruses, and of Dr. R. Koenig, Institute for Virus Serology, Germany, for studies on APLV and APMV.

### PSTV

Potato spindle tuber is caused by a viroid, a single-stranded ribonucleic acid particle without a protein coat, which is transmitted with usually low efficiency through pollen and ovary to botanical seed of the potato. The virus has been reported in Canada, USA, USSR, China, Poland, and Korea in potatoes, and in South Africa in tomatoes.

In contract research at Cornell University, the sensitivity of detection of PSTV by slab polyacrylamide gel electrophoresis (PAGE) was evaluated against tomato challenge inoculation. While 25 samples could be tested by PAGE in a day and a half, up to eight weeks and considerable greenhouse space are required for the tomato challenge assay. In a test with 146 Cornell breeding lines for PSTV by both PAGE and tomato assay, results were in agreement in 123 cases. In 23 cases, results of the original tests were not in agreement; when 20 were tested a second time, results supported the original PAGE data in all but one case. It was concluded that the PAGE assay for PSTV is more rapid and reliable than the tomato bioassay.

## Antisera Production and Techniques for Virus Detection

The antisera production project has the following objectives: 1) To produce antisera to the more common potato viruses in sufficient quantities for: a) distribution to national programs in developing countries, b) routine virus checks in the CIP seed program and in virus research, and, c) developing improved serological techniques for efficient detection of viruses in large scale seed programs; 2) To produce antisera to new or little known viruses affecting potato.

The assistance in producing the following antisera by Ing. C.E. Fribourg, of the National Agriculture University, La Molina, is gratefully acknowledged:

Potato Virus X, strains C and HB
Potato Virus Y
Potato Virus S
Andean Potato Latent Virus, strain Hu
Andean Potato Mottle Virus, type strain
Tobacco Ringspot, potato calico strain
Wild Potato Mosaic Virus

The distribution of antisera to developing countries is summarized in Table 13. Sera are normally sent in concentrated form, mixed with glycerine and sodium azide, as preservative. Usually a sufficient quantity of sera for 1,000 to 2,500 tests with each virus is sent, accompanied by information sheets detailing the methodology used for microprecipitation and gel diffusion testing.

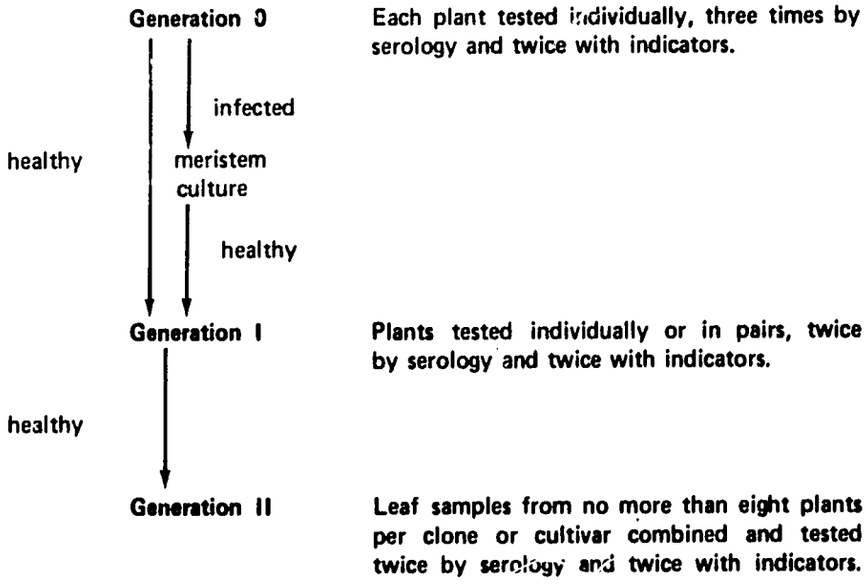
**Table 13 – Number of samples of antisera distributed to developing countries, 1975 - 1977**

| Country | Antisera | | | | | |
|---|---|---|---|---|---|---|
| | PVX | PVY | PVS | TRSV | APLV | APMV |
| Bolivia | 1 | 1 | 1 | 1 | 1 | 1 |
| Brazil | 2 | 1 | 2 | 1 | | |
| Chile | 1 | 1 | 1 | 1 | 1 | |
| Colombia | 2 | 2 | 2 | | 1 | |
| India | | | | | 1 | |
| Korea. | 2 | 2 | 2 | | 2 | 1 |
| Mexico | 3 | 2 | 4 | 1 | 2 | |
| Nepal | 1 | 1 | 1 | | | |
| Paraguay | 1 | | | | | |
| Peru | 3 | 3 | 3 | 1 | 3 | |
| Philippines | 1 | 1 | 1 | | | |
| Thailand | | 1 | | | | |
| Tunisia | 1 | 1 | | | | |
| Turkey | 2 | 2 | 2 | | 1 | |
| Venezuela | 2 | 2 | 2 | | 1 | |
| Zambia | 1 | 1 | | | 1 | |
| | 23 | 21 | 21 | 5 | 14 | 2 |

Requests have also been met for antisera from several developed countries: for APLV, Canada, USA, Hungary; and, for PVX, PVY, PVS, TRSV and APLV, England and the Netherlands.

Very high standards of virus testing are maintained at CIP to avoid export of infected material as either multi-meristem cultures, rooted cuttings or tubers. A schedule to test for viruses has been designed to ensure that material for export from Peru is as free from viruses as modern technology permits (Table 14).

**Table 14 – Sequence of testing to detect and eliminate viruses from multi-meristem cultures, rooted cuttings and tubers for export**



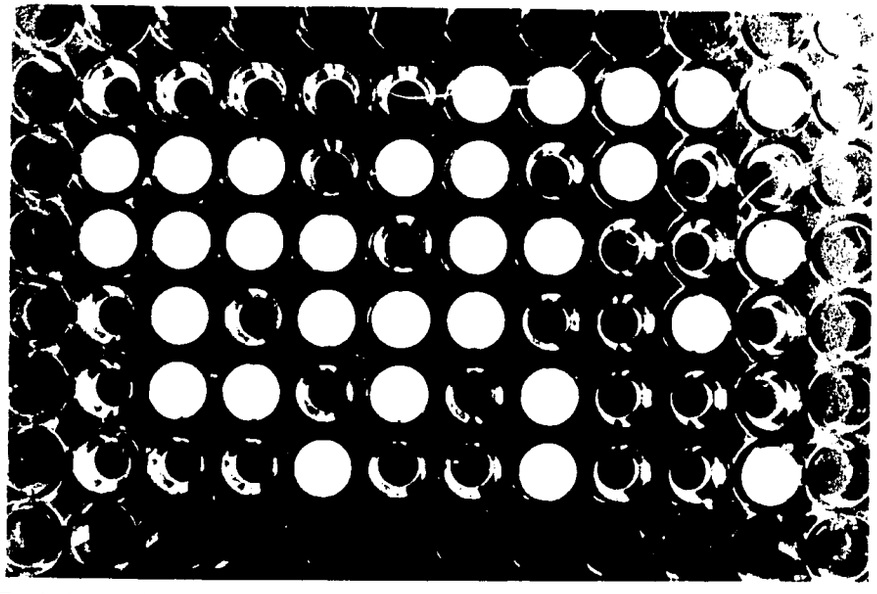

The different checks are always done at least one month apart. The indicator hosts used routinely are listed in Table 15.

Routine serology checks are carried out with sera to PVX, PVY, PVS, APLV and APMV. Initially microprecipitation was used for the serological detection of PVX, PVY and PVS and gel diffusion for APLV and APMV. In August, 1977, a change was made to the latex method for all five viruses. This test has the advantage of being more rapid, easier to read, uses less antisera and is considerably more sensitive than microprecipitation.

In addition to the latex test, studies are continuing in a comparative evaluation of enzyme-linked immunosorbent assay (ELISA). ELISA is demonstrably more sensitive than the latex test and is particularly useful in screening plantlets from tissue culture. With both the latex and ELISA tests, combined antisera can be used in serological assays. The use of single diffusion in agar, being relatively insensitive, has been discontinued.

**Table 15 — Range of indicator plants used for detecting potato viruses in the CIP seed export program**

| Species | Viruses |
|---|---|
| *Chenopodium quinoa* — *C. amaranticolor* | PVS, TRSV, PVT TRV, PMTV (PVM) |
| *Gomphrena globosa* | PVX, (PVS, PVM) |
| *Nicotiana glutinosa* — *N. tabacum* | PVA, PVY, PAMV (PVX) |
| *N. debneyi* | (PVM, PVS) |
| *N. bigelovii* — *N. clevelandii* | APLV, APMV |



**Typical reaction of Andean Potato Mottle Virus – infected samples in the ELISA test**

During 1977 a Joel JEM 1005 model transmission electron microscope was installed. This instrument has a resolution of 3.4 angstroms (line to line) with a magnification to 200,000. The microscope has been erected on a seismic base. Initially the microscope is being used for the routine detection and identification of viruses. Planned use for other disciplines is also intended.

# CONTROL OF IMPORTANT NEMATODE AND INSECT PESTS OF POTATOES

Breeding and screening for resistance continued to receive major emphasis in nematode research during 1977. Research was confined to two species of cyst nematodes (*Globodera rostochiensis* and *G. pallida*), to the root-knot nematode (*Meloidogyne incognita acrita*) and the false root-knot nematode (*Nacobbus aberrans* complex). Although pockets of cyst nematodes are found in restricted areas in many developing countries, the importance of cyst nematodes in the Andean zone has influenced research emphasis toward problems of this region. Root-knot nematodes tend to be cosmopolitan in warmer areas of the tropics.

## Cyst Nematodes

Two clones of *Solanum andigena*, 702535 and 702698, from the CIP germ plasm collection were rated highly resistant to the Huancayo cyst nematode population (*G. pallida*) and somewhat resistant to Otuzco and Cuzco populations (*G. pallida*), as well as a population from Puno (*G. rostochiensis*). This type of resistance has only been recently identified and is most likely broadly based.

In intercrosses between partially resistant clones of *S. andigena*, it has been found possible to raise the level of resistance through strong selection among the progeny. Apparently "minor" genes are involved. Evaluation of resistance in plants grown from tubers has been shown to be more reliable than seedling assays. From 1,981 progeny derived from crosses of resistant and susceptible *andigena* clones, about one-third were rated resistant. Up to 80 percent of progeny with resistance to an Otuzco cyst nematode population was derived from clone 701422. About 10 percent of the progeny derived from clone 701478 were resistant to both the Otuzco and Cuzco populations.

Possibly a more productive breeding approach for generalized resistance involves crosses between resistant *S. andigena* and resistant hybrids of wild clones x *S. tuberosum* (Table 16).

**Table 16 – Resistance to cyst nematode populations in progeny of crosses between selected *Solanum tuberosum* spp. *andigena* clones and hybrids of wild species and *S. tuberosum***

| Cross | Numbers resistant (R) or susceptible (S) to cyst populations* | | | |
|---|---|---|---|---|
| | Otuzco R : S | Huancayo R : S | Cuzco R : S | Puno R : S |
| 701422 x 4-46 | 23 : 16 | 19 : 19 | | 10 : 15 |
| 702770 x U7950 | 6 : 15 | | 24 : 26 | 10 : 13 |
| 66.1004-11 x 701421 | 14 : 14 | 10 : 14 | 7 : 4 | 11 : 6 |
| 66.1004-11 x 701422 | 37 : 26 | 21 : 53 | 29 : 32 | 18 : 29 |
| 66.1004-11 x 701498 | 36 : 21 | 8 : 25 | 17 : 10 | 24 : 3 |
| 600002 x 701421 | 22 : 55 | 20 : 7 | 66 : 0 | 52 : 6 |
| MSIE.7 x VK 69.491 | 0 : 44 | 13 : 18 | 19 : 17 | 175 : 38 |
| M.S.35.22 x VK 69.491 | 20 : 112 | 17 : 23 | 38 : 9 | 120 : 4 |

* The cyst nematode populations from Otuzco, Huancayo and Cuzco were *Globodera pallida*; the Puno population was predominantly *G. rostochiensis*.

A total of approximately 2,500 clones were provided for screening through contract research at Cornell University. These were obtained from intercrosses involving *S. multidissectum*, *S. sanctae-rosae*, *S. spegazzini*, *S. chacoense*, *S. tarijense*, *S. vernei* and *S. andigena*. In trials in Peru, 360 clones were selected for resistance against both Huancayo and Otuzco cyst nematode populations. Rootballs with 20 or fewer cysts were scored as resistant. Intercrosses of *S. sanctae-rosae*, *S. chacoense* and *S. vernei* were considered to be the best sources of resistance. After rechecking for resistance, selected clones will be crossed with *S. andigena* to improve their tuber quality as well as resistance. Nearly all clones were successfully increased in 1977 to allow replicate testing at both Cornell and in Peru.

At Cornell, 14 progenies involving *S. kurtzianum*, *S. chacoense*, *S. verrucosum* and *S. sparsipilum* were grown in 1977, together with 40 plant introductions of 25 species from the Sturgeon Bay IR-1 collection. Fifty-eight new interspecific diploids and 13 tetraploids were produced for 1978 tuber tests.

Frost-resistant clones of *S. acaule* selected at CIP were screened for resistance to Otuzco and Huancayo nematodes. Of 90 clones, H 474078-20, H 474078-3D, H 474081-3HD and H 474083-ID were resistant to both cyst populations. In a separate study, dual resistance to *Globodera pallida* and *Synchytrium endobioticum* (wart) was examined in 499 clones of S. tbr. ssp. *andigena* derived from crosses of six selected clones. Encouraging levels of dual resistance were found in some of the 274 clones with varying cyst nematode resistance.

Field trials for tolerance to cyst nematode rather than resistance, were repeated in Chocon during 1977 in heavily infested plots (120 eggs/gm soil). Three clones each of tolerant, intolerant and control varieties in replicate plots, with and without a nematicide, were evaluated for yield. Under conditions of heavy cyst nematode infestation yield losses of less than 35 percent were considered to be tolerant in comparison with nematicides treated controls (Fig. 5). Tolerance, being pathotype independent, when combined with resistance is of practical value where cyst nematodes are widespread and pathotypes are diverse.

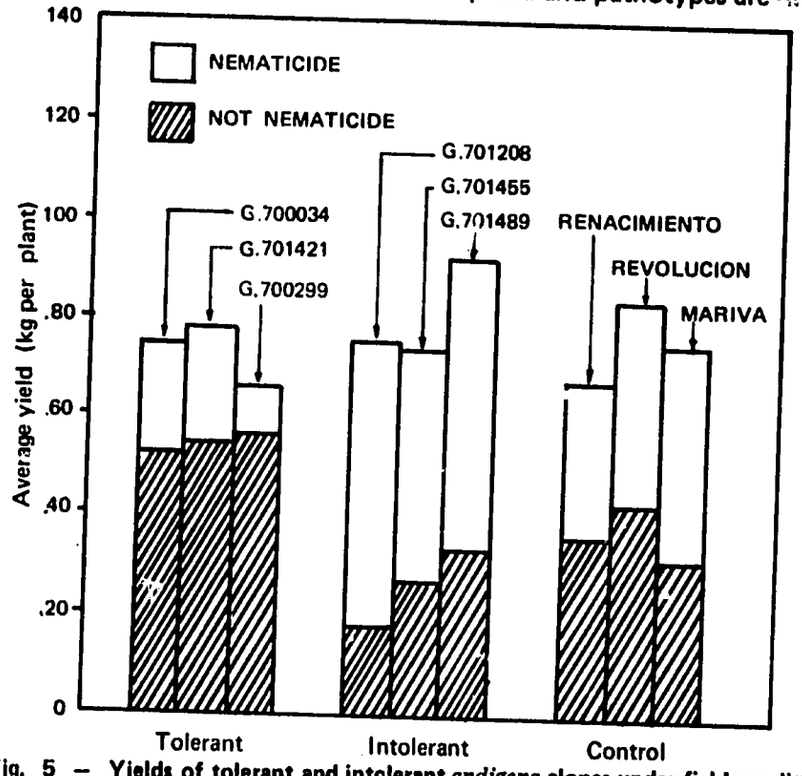



Fig. 5 – Yields of tolerant and intolerant *andigena* clones under field conditions during two seasons (Revolucion, Mariva and Clone G 700299 were tested during one season).

Characterization of Andean and other populations of potato cyst nematodes was part of doctoral research conducted by a CIP staff member at Rothamsted Experimental Station, England, during 1977. Clones with resistant genes $H_1$, $H_2$ and $H_3$ were tested against 44 Andean and nine European populations. Results showed that the Andean populations of nematodes have a wider variability than the European populations and are able to overcome H genes. Gene $H_3$ reduces reproduction of the Huancayo and Otuzco populations and appears to be similar to the partial resistance of some *G. pallida* populations identified in the germ plasm collection.

When some populations were tested using cuttings of Maris Piper ($H_1$ genes, ex-andigena) and other varieties containing $H_2$ and $H_3$ genes, the presence of *G. rostochiensis* pathotypes which overcame the $H_1$ resistance gene were identified in populations from Peru, Bolivia and Italy. Populations of *G. pallida* on plants with $H_2$ and $H_3$ genes behaved variably with many populations reproducing freely.

Both intrinsic genetic variation, environmental factors and measurement techniques can contribute to variation in second stage larvae and cyst terminal areas. In a study of 161 populations, stylet length and distance from head tip to excretory pore in second stage larvae, and fenestral length and number of ridges between the anal pore and vulval fenestra in cyst terminal areas were the most stable features in *Globodera* speciation. It is recommended that 15 observations per population be used in species identification. Comparisons of areas and perimeters of second stage larvae and males of previously identified populations were found to be unreliable for identification as determined by an Image Analizing Computer.

In a comparative study of the biology of some selected populations, there appears to be no fundamental differences between British and Peruvian populations of the same species. However, the Peruvian population of *G. pallida* is less sensitive to temperature extremes than the "white" British *G. pallida*. In general, *G. pallida* populations showed better adaptation to low temperatures than those of *G. rostochiensis*. Daylength had an indirect effect through the host on the rate of invasion and development of both species.

Studies using protein gel electrophoresis of immature females, scan electron microscopy and controlled matings of British and Peruvian populations of *G. rostochiensis* showed no differences between them. Instraspecific matings between populations from various places of origin were successful.

In studies of the geographical distribution, the two species coexist around latitude 15° S. North of this latitude in Peru, the populations are exclusively *G. pallida*; southward along the Andes, and especially around Lake Titicaca, *G. rostochiensis* predominates, although *G. pallida* may also be found. It is probable that the pest was introduced into Europe in the late 1840's where it became established and was first reported in 1881.

Although data were collected during 1977 on the influence of latitude, soil type and host varieties on different populations of cyst nematodes many of the results were equivocal. In general both species of *Globodera* reproduced better at southern latitudes (16 – 17° S) than farther north (7 – 12° S). Soil types had a marked influence on reproduction; reproduction of both species on soil from Arequipa, was 10 times as prolific as soils from Tarma and Cajamarca. It was not evident from detailed soil analysis – including electrical conductance, pH, organic matter level, textural class, component fractions, available nutrients, percent N and exchangeable cations – which factor or combination of factors contributed to the wide variation in reproduction in the soils tested.

Interplanting of *Tagetes minuta*, *Lupinus alba* and *Mentha viridis* with potatoes dramatically reduced reproduction of *G. rostochiensis* but not *G. pallida*. Conversely, interplanting of *Chenopodium quinoa* var. Sajama and *Cucurbita maxima* increased the reproductive rate of *G. pallida* yet had no apparent influence on *G. rostochiensis*.

## Root-knot Nematodes

In 1977, 1,937 clones from the CIP germ plasm collection were tested for resistance to the root-knot nematode, *Meloidogyne incognita acrita*. Only 19 clones exhibited some degree of resistance and had a trace of root infection by this pest.

The present status of testing cultivated potatoes for resistance to *M. incognita acrita* is presented in Table 17. Since the degree and frequency of resistance in the cultivated potato is rather low, intercrossing resistant material, as well as outcrossing to selected genotypes, is being considered to fully utilize these genetic resources. Data indicate that tuber and root infections are independent and there is no correlation in resistance of these structures to nematode infection.

**Table 17 – Cultivated potato material tested for resistance to *Meloidogyne incognita acrita* from 1974 - 1977**

| Material tested | No. of clones | Percent resistance | Levels of resistance |
|---|---|---|---|
| Germ plasm | 5865 | 1.8 | Low |
| Diploid | 850 | 2.7 | Low |
| Other selections | 750 | 1.9 | Low |

In another study, the reaction of 62 tuber-bearing *Solanum* species – consisting of 254 accessions and 3,661 genotypes – to *M. incognita acrita* was evaluated under screenhouse conditions (Table 18).

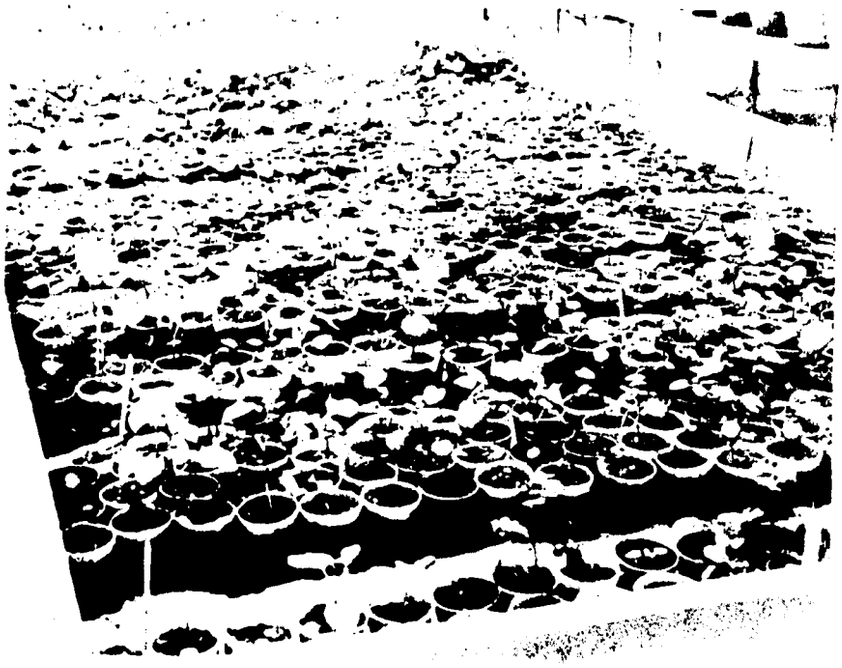
**Table 18 – Summary of reactions of tuber-bearing *Solanum* species to *Meloidogyne incognita acrita*, 1974 - 1977**

| Source | No. tested | Resistance | |
|---|---|---|---|
| | | Percent | Level |
| Species | 64 (62) * | 70.3 (12.9) | Low to very high |
| Accessions | 416 (254) | 34.1 ( 5.5) | Low to very high |
| Genotypes | 8060 (3661) | 5.2 ( 0.8) | Low to very high |

* Data in parentheses were obtained from October 1976 - October 1977.

Plants with high levels of resistance and immunity will continue to be retested and used in breeding for resistance to root-knot nematode.

A new method using 4 oz. plastic cups as well as a suitable soil mixture was developed for seedling screening. Young seedlings approximately 5-10 cm tall were transplanted in the plastic cups containing a sterilized potting soil mixture of either 1:1 sand: Jiffy mix, or 2:2:1 sand: Jiffy mix: Pomacocha soil. Two weeks later the plants were inoculated with 4,000 root-knot nematode eggs and were allowed to grow for six to eight weeks prior to evaluation for resistance. This method provides an efficient and rapid screening procedure for a large number of plants as well as pathotypes of both root-knot and cyst nematodes.



Plastic cups (4 oz.) used in a rapid, mass screening procedure for resistance to nematodes.

Elsewhere in this report (Thrust V) the pathogenic interaction between *M. incognita acrita* and *Pseudomonas* has been mentioned. It is of particular interest to note in studying the interaction of these two organisms on *Meloidogyne* immune, resistant and susceptible plants, that root infection by nematodes as expressed by root galling index was directly correlated with bacterial symptoms as expressed by percent plants wilted (Table 19). Reaction of *Solanum sparsipilum* and *S. chacoense* (root-knot nematode immune and resistant plants respectively) to *P. solanacearum* was directly correlated with their reaction to *Meloidogyne*.

**Table 19 – Interrelationship of *Meloidogyne incognita acrita* and *Pseudomonas solanacearum*, isolate 013 (race 3) on selected *Solanum* spp.**

| | Percent plants wilted | | |
|---|---|---|---|
| | *S. sparsipilum* | *S. chacoense* | tbr x adg ctvr "Mariva" |
| Check | 0 | 0 | 0 |
| *M. incognita acrita* | 0 (0) * | 0 (1.2) | 0 (3) |
| *P. solanacearum* | 0 | 5 | 45 |
| Both organisms | 13 (0) | 30 (1.2) | 85 (3) |

* Numbers in parentheses show reaction to nematode infection as based on root galling on a scale of:
0 = No root galling and/or nematode reproduction;
4 = Very severe root galling and/or a very high nematode reproduction.

In another interaction study, depression of cyst nematode development was observed on plants inoculated simultaneously with *Globodera pallida* and with a fungus, either *Phoma exigua*, *P. exigua* var. *nonoxydabilis*, *P. andinum* sp. nov, or *Collectotrichum coccodes*. No cyst infection by the fungi was noted in the cysts examined. Apparently fungi used in this study infected roots in the presence of *G. pallida*, a factor which may have retarded nematode development.

A comprehensive taxonomic study of the false root-knot nematodes (*Nacobbus* species) attacking potatoes was undertaken in cooperation with Dr. A. M. Golden, USDA nematologist, Beltsville, Maryland. A total of 26 populations collected from Argentina, Bolivia, Ecuador and Peru were examined morphologically for taxonomic identification.

Based on morphometrics of populations examined and on original description of *N. aberrans* and its three synonyms (as revised by Sher in 1970), all false root-knot nematodes attacking the potato in South America, up to the present time, are considered to be of the *N. aberrans* species complex involving two or more forms rather than a single homogeneous species.

As part of a study of the biology of *N. aberrans*, survival of the nematode under desiccation was investigated. Soil samples and infected roots collected from a heavily infested field were air-dried for four weeks. Samples of moist infested soil and infested air-dried soil were processed for nematodes. No vermiform nematodes were found in the air-dried soil. A similar number of egg masses containing viable eggs was found in both moist and air-dried soil (Table 20). The data indicate that *N. aberrans* can withstand desiccation and that eggs are the primary means of survival under drought conditions.

**Table 20 – Survival of *Nacobbus aberrans* under conditions of desiccation**

| Source of inoculum | Root galling index * |
|---|---|
| Moist infested soil | 2.5 |
| Dried infested soil (R. H. 8.7 percent) | 2.2 |
| Dried galled roots | 2.2 |
| Fresh galled roots | 2.3 |
| Control | 0 |

* Root galling index determined by root infection:
0 = No root galling and/or nematode reproduction;
4 = Very severe root galling and/or nematode reproduction.

## Entomological Research

Studies of the resistance to potato-infesting insects were continued during 1977 in contract research at Cornell University. Ninety-seven and 42 $F_1$ clones of *Solanum tuberosum* ssp. *andigena* selected for reduced infestations of the green peach aphid (*Myzus persicae*) and potato leaf hopper (*Empoasca fabae*), respectively, were retested in replicate plots. Seven clones (R301-112, R844-3, R844-123, R845-49, T121-3, T121-60 and T121-114) reduced aphid infestations by 85 percent or more below Katahdin controls. Three clones (R111-4, R298-106 and R699-52) had *E. fabae* nymph infestations 50 percent or less than Katahdin.

Thirty accessions of wild, tuber-bearing *Solanum* species differentially resistant to infestation by *M. persicae* and *E. fabae* were reevaluated in replicated trials. Accessions of *S. acaule*, *S. berthaultii*, *S. chacoense*, *S. polyadenium* and *S. polytrichon* averaged 90 percent or higher reduction in infestation by the potato leaf hopper compared to Katahdin, Superior and Kennebec. *S. berthaultii*, *S. bulbocastanum* and *S. polyadenium* had similar reductions in green peach aphids, compared to susceptible checks. Clearly, these studies demonstrate a potential for developing insect-resistant breeding lines.

The nature of insect resistance was examined from chemical and physical points of view. Foliage of 11 species, differentially-resistant to nymphal infestation of *E. fabae* in 1976 field trials, were analyzed in 1977 for total glycoalkaloids (TGA). Levels of TGA ranged from a low of 13 mg/100 g fresh weight in *S. bulbocastanum* (PI 275194) to a high of 688 mg/100 g gresh weight in *S. polyadenium* (PI 161728), for a range of about 50-fold. Nymphal infestation of *E. fabae* and TGA (percent fresh weight) were highly correlated (R = - 0.75). With the exception of *S. berthaultii*, accessions resistant on the basis of nymphal infestation had a level of 0.17 percent TGA or greater, while those of susceptible accessions had a level of 0.05 percent TGA or less, fresh weight.

**Typical galls on the roots of potatoes infested with false root-knot nematodes,** *Nacobbus aberrans.*

In cooperative research with Rothamsted Experimental Station, England, and Cornell University contract research, *E. fabae* resistance due to the presence of glandular trichomes was evaluated (Table 21). Accessions of *S. berthaultii* with both simple and four-lobed glandular trichomes had more of a tendency for smaller infestations than those with four-lobed trichomes alone.

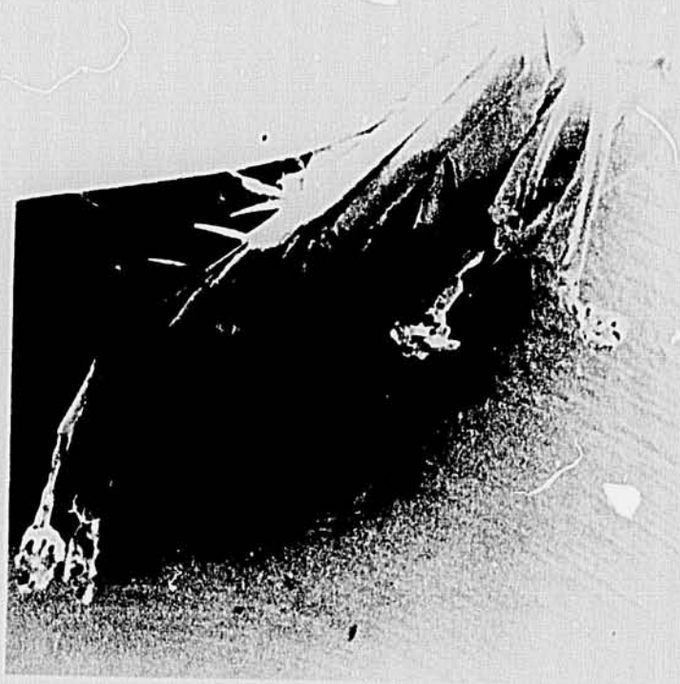
With respect to individual glycoalkaloids, tomatine at concentrations from 0.05 – 0.6 percent of a synthetic diet was extremely toxic to *E. fabae* nymphs. (A diet containing 0.6 percent tomatine is equivalent to TGA levels in fresh *S. polyadenium* foliage.) Alpha-solanine at the same concentration had no effect on survival.

Table 21 – Mean infestations of potato leaf hopper adults, *Empoasca fabae*, on 12 accessions of *Solanum berthaultii* and two clones of *S. tuberosum*

| Species | Accession | Trichome type 4-lobed | Trichome type Simple | *E. fabae*/3 plants No. |
|---|---|---|---|---|
| *S. berthaultii* | PI 310927 | | | 1.3 a * |
| " | HHC 4422 | | | 1.3 a |
| " | HHC 4531 | | | 1.8 ab |
| " | PI 265858 | | | 2.0 ab |
| " | PI 218215 | | | 2.7 abc |
| " | HHC 4727 | | | 3.1 bc |
| " | HHC 4543 | | | 3.4 bc |
| " | HHC 4562 | | | 3.5 bc |
| " | PI 310971 | | | 3.9 bc |
| " | HHC 4538 | | | 5.1 c |
| " | PI 283069 | | | 6.2 c |
| " | HHC 4570 | | | 6.3 c |
| *S. tuberosum* | Superior | | | 37.9 d |
| " | Katahdin | | | 48.9 d |
| | | | | F : 18.7 |

* Means followed by the same letter(s) are not significantly different at P = 0.05 by Duncan's Multiple Range Test.

Adults and nymphs of *E. fabae* confined on foliage of *S. polyadenium* accumulate trichome exudate on mouth parts and tarsi, leading to early death due to impaired feeding mobility. In field tests, resistance of *S. polyadenium* was equal to that of *S. berthaultii*.



**Adult of the potato leaf hopper (*Empoasca fabae*) showing an accumulation of trichome exudate on feet and mouth parts.**

*S. polyadenium* has two types of insect resistance: glandular trichomes and relatively high levels of toxic glycoalkaloids. The aggressive feeding of the adult Andean weevil, *Premnotrypes suturicallus* appears to be inhibited by both chemical and physical factors. In a laboratory

experiment in which adult weevils were confined on leaf discs of a number of different *Solanum* species, *S. polyadenium* proved to be more resistant to feeding injury than the other tested species. When leaf surfaces of *S. polyadenium* were wiped with tissue paper to remove glandular hairs there was a significant increase in foliage feeding (Table 22).

**Table 22 – Assay of feeding on leaves of wild *Solanum* species by Andean weevil adults**

| Host | Accession no. | Leaf disc consumed * $mm^2$ |
|---|---|---|
| *S. polyadenium* | PI 320342 | 3.25 a ** |
| " (wiped) | | 4.46 b |
| *S. berthaultii* | PI 265858 | 7.66 c |
| *S. kurtzianum* | PI 133687 x 133695 | 7.82 c |
| *S. tarijense* | HHG 4746 | 7.93 c |
| *S. chacoense* | PI 230582 | 8.15 c |
| *S. tuberosum* ssp. *andigena* var. Sipeña | | 8.36 c |

* All data transformed to $\log_{10}$ scale. Means of four replicates separated by Tukey test ALS (T) 0.01 = 0.725.

** Means followed by the same letter are not significantly different at P = 0.05 by Duncan's Multiple Range Test.

The inheritance of simple, non-lobed, exudate-secreting trichomes is being studies. In hybrids derived from crosses between the diploids *S. phureja* and *S. berthaultii*, a ratio of four non-glandular, nine rudimentary glandular and three sticky glandular hairs were distinguished in the $F_2$ generation. In an $F_2$ population, 19 of 282 hybrids seedlings from a tetraploid (*S. tuberosum* var. Pentland Crown) x diploid (*S. berthaultii*) cross had sticky, simple trichomes. Both ratios were similar to those expected if the development of this type of hair is controlled by two genes, one dominant and one recessive. This hypothesis will be tested by further crossings.

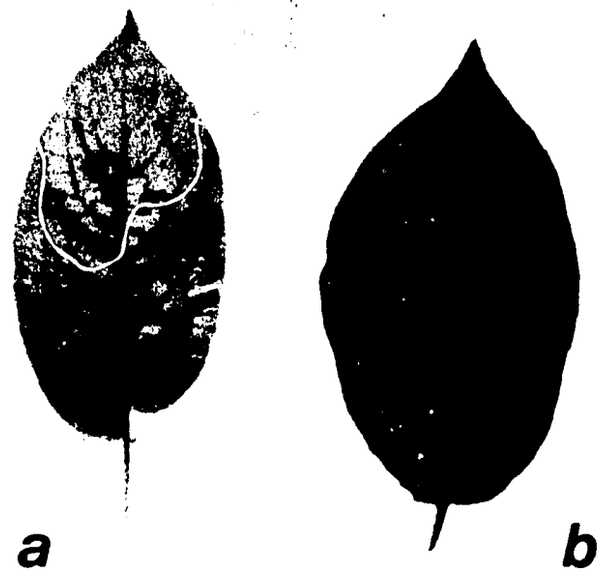
Almost all the seedlings without sticky tips could be eliminated by visual examination before transplanting. All plants selected among the *S. tuberosum* hybrids proved capable of trapping a proportion of the mite, *Polyphagotarsonemus latus*. When adults of a larger mite, *Tetranychus urticae*, were placed on tetraploid hybrid leaflets all were captured by the exudate on the simple hairs. A high density of glandular trichomes appears to be important in trapping very small mites.

Studies were resumed to confirm the identification of virus-like particles transmitted through the action of the ovipositor by the female leaf miner fly, *Liriomyza huidobrensis*. These rod-shaped particles have been transmitted to "Samsun" tobacco plants with a high frequency by leaf miner flies collected from several hosts in the field (Table 23). Although the particles have been purified from infected "Samsun" tobacco plants using a technique for PVY isolation, tobacco plants checked serologically against PVX, PVY, PVS, andean potato latent virus and andean potato mottle virus gave negative results.

**Table 23 – Infection of the indicator host, *Nicotiana tabacum* var. "Samsun", by virus-like particles transmitted by *Liriomyza huidobrensis*, the leaf miner fly**

| Field host | No./plant flies | No. of "Samsun" plants | |
|---|---|---|---|
| | | Inoculated | Infected |
| Potato | 20 | 10 | 10 |
| Potato | 10 | 6 | 4 |
| Cabbage | 1 | 7 | 7 |
| Lettuce | 1 | 7 | 7 |
| Pea | 1 | 4 | 3 |

The leaf miner fly causes feeding injury and also larval tunneling injury in potato foliage. The feeding injury is due to punctures made by the female ovipositor, the leaf sap which exudes from the puncture being consumed by flies of both sexes.




**Tunneling injury (a) and feeding injury (b) caused by leaf miner fly, *Liriomyza huidobrensis*, on potato leaves.**

Resistance to leaf miner fly injury was evaluated during 1977 in 10 commercial varieties at El Asesor and in the coastal Cañete Valley, Peru. Percentage of foliage damage was rated in 30-plant plots laid out in a randomized complete block design.

The variety "Tomasa Condemayta" had significantly less larval tunneling injury (15 percent) than "Mariva" (21.8 percent) and "Ticahuasi" (22 percent), which in turn were more resistant than the remaining seven varieties tested.

Feeding injury associated with ovipositor punctures in foliage was evaluated in discs 12 mm in diameter. Evaluation of data by Duncan's Multiple Range Test showed that the variety "Merpata" had significantly less feeding injury than "Tomasa Condemayta", or "Mariva". A direct correlation between ovipositor injury associated with feeding and reproductive activity has been established only in the case of the variety "Renacimiento".

**Comparison of leaf miner larvae (*Liriomyza huidobrensis*) tunneling injury in susceptible and resistant potato varieties.**

The potato tuber worm, *Phthorimaea operculella*, is a serious pest in many parts of the tropical and subtropical world. Eggs are laid singly, usually on the underside of leaves. The emerging larvae penetrate and mine leaves, often tunneling into leaf veins and continuing down inside the stem to the developing tubers. Infestation in potato storages is initiated by storing infected tubers or by entrance of moths into the storage.

During 1977, field studies were undertaken in cooperation with the Laboratory for Research on Insecticides, Wageningen, the Netherlands, to evaluate the effectiveness of a synthetic pheromone in attracting and trapping male tuber moths. (Sex pheromones, produced by the mating female tuber moths, attract male tuber moths.) The effectiveness of the synthetic pheromone is apparent in that 22,225 male moths were trapped during 31 days, an average of 717 moths per night in a single water trap. During the same period, 11 males were trapped in a water control trap. In a second trap 23,537 males, 759 per night, were trapped compared to a total of seven males in a control trap. A maximum of 3,895 moths were trapped in a single night (Fig. 6).

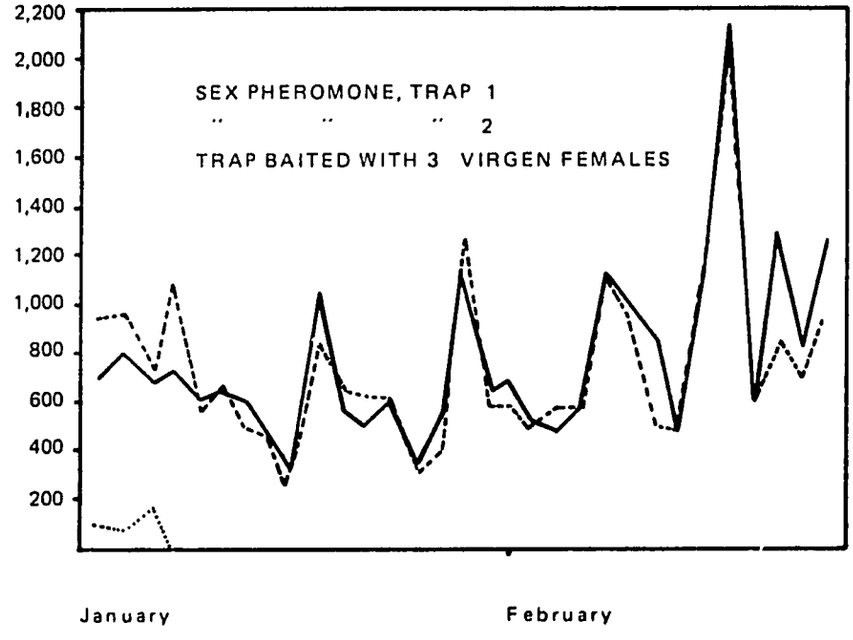


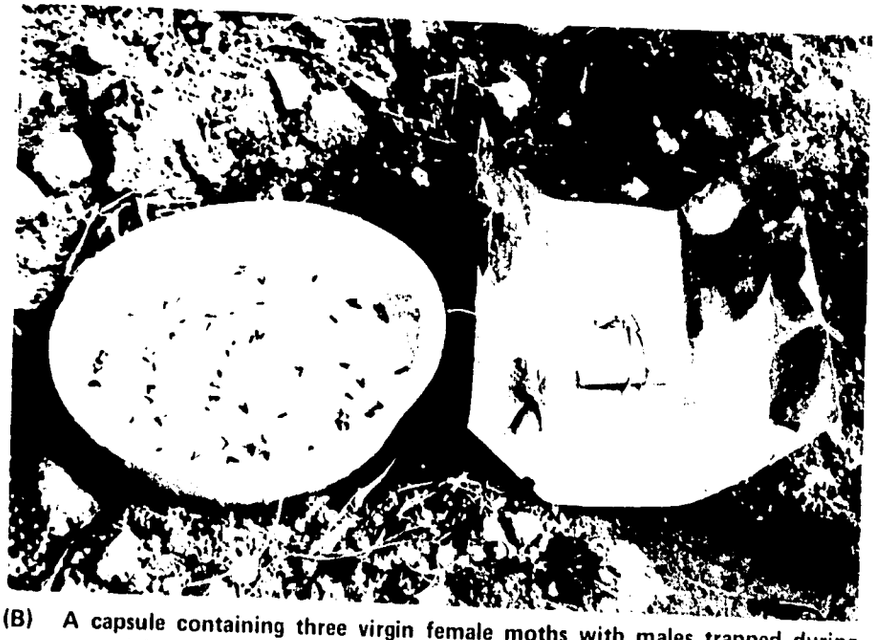

**Fig. 6 — Male potato tuber moths per trap per night during sex attractant evaluation in the field.**

In addition to the simplicity of the traps employed, the synthetic pheromone maintained its activity under field conditions for more than one year. Impregnation of the pheromone into several types of rubber appeared to be equally effective in attracting male moths.

The identification of aphids under field conditions is usually very difficult for technicians. During the year an illustrated brochure was prepared to assist in the identification of six important potato aphids. In addition to descriptive information on feeding habits and gross visible characters, descriptive photographs of diagnostic features visible under a hand lens were included.

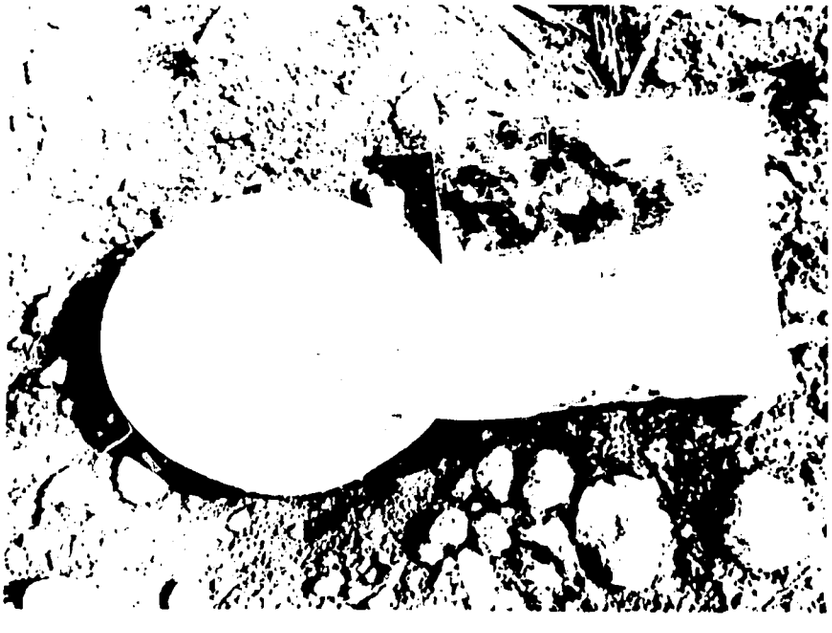
Field trapping of male tuber moths, *Phthorimaea operculella*, by a synthetic sex attractant

(A) Field trap consisting of water-filled plastic dish and an aluminium cover from which pheromone-impregnated rubber tubing is suspended. The netting is to camouflage the aluminium cover.



(B) A capsule containing three virgin female moths with males trapped during one night.

(C) Males trapped during one night by synthetic pheromone impregnated in rubber.



(D) Control, no pheromone.

# PHYSIOLOGICAL AND AGRONOMIC MANAGEMENT OF POTATOES ADAPTED TO ENVIRONMENTAL STRESS

The potential of the potato as a source of food for developing countries of the equatorial belt, between 30° N and 30° S, lies in selecting genotypes adapted to diverse environments. Not the least of the barriers to acceptance of this potential has been the widely held concept that the potato is a temperate zone crop.

This view ignores the photoperiodic elasticity of the potato which thrives in a nine-hour daylength range, between a long Scandinavian summer day and a short tropical winter day. Its latitudinal growth range of over 100° exceeds that of most other crops. The capacity of the potato to grow in a 4,300 m altitude range is challenged by few cultivated plants. Its adaptability to grow in a 43° C temperature range is an indication of its genetic diversity. Its growing season can be from two to five or six months, reflecting the flexible response of potato clones to ranges in temperature, daylength and water and nutrient availability.

## Heat Stress

In the development of heat-tolerant potatoes, clones and seedling populations have been evaluated for yield directly in the field under conditions of high temperature stress. A temperature of 21° C, at a soil depth of 15 cm, has been selected as an arbitrary minimum for testing heat tolerance. The climate at Yurimaguas, located in the Amazon basin at 180 m, is highly favorable for large-scale field tests of heat tolerance.

From the data presented in Table 24 is apparent the general uniformity of temperature throughout the year. The mean monthly maximum has a range of 34.5 ± 1° C; the mean monthly minimum a range of 19 ± 2° C while the mean daily temperature fluctuates less than 1.5° C throughout the year. Other data collected at San Ramon, located in a high jungle area at 800 m, shows the relation of air temperature to soil temperature (Table 25).

**Table 24 – Temperature, evapotranspiration and precipitation data, Yurimaguas, Peru**

| | Monthly temperature (° C) and precipitation (mm) * | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | F | M | A | M | J | J | A | S | O | N | D |
| Mean maximum | 34.9 | 34.9 | 34.8 | 34.4 | 34.1 | 33.9 | 33.6 | 34.5 | 34.9 | 35.2 | 35.5 | 34.5 |
| Mean minimum | 20.7 | 20.4 | 21.2 | 20.2 | 19.7 | 18.6 | 17.0 | 18.1 | 19.3 | 19.4 | 20.5 | 21.1 |
| Mean daily | 26.7 | 26.6 | 26.4 | 26.6 | 26.1 | 26.2 | 26.2 | 26.7 | 27.0 | 27.3 | 27.2 | 27.1 |
| Evapotrans-piration | 145 | 126 | 140 | 123 | 118 | 108 | 124 | 143 | 147 | 156 | 148 | 148 |
| Precipitation | 218 | 207 | 195 | 198 | 178 | 113 | 113 | 88 | 141 | 189 | 178 | 191 |

* Temperature data are averages for 25 years; evapotranspiration and precipitation data are averages for 10 years. Servicio Nacional de Metereología e Hidrología, Peru.

**Table 25 – Temperature data during the season June to September, 1976, San Ramon, Peru**

| | | Air temperature, ° C | | Soil temperature, ° C | | | |
|---|---|---|---|---|---|---|---|
| | | | | 5 cm | | 20 cm | |
| Date | | Max. | Min. | Max. | Min. | Max. | Min. |
| June | 15 - 30 | 27.8 | 15.5 | 31.1 | 19.8 | 25.3 | 21.8 |
| July | 1 - 15 | 27.0 | 14.9 | 30.5 | 19.4 | 24.3 | 22.2 |
| July | 16 - 30 | 28.8 | 15.0 | 32.3 | 20.2 | 26.0 | 22.1 |
| August | 1 - 15 | 27.3 | 17.2 | 30.3 | 20.7 | 25.5 | 22.2 |
| August | 16 - 30 | 26.2 | 15.2 | 30.7 | 20.5 | 25.6 | 22.5 |
| September | 1 - 15 | 24.3 | 17.1 | 27.7 | 20.1 | 23.7 | 22.2 |
| September | 16 - 30 | 29.7 | 17.2 | 30.4 | 21.3 | 26.8 | 22.5 |

Because little is known about the physiology of heat tolerance, studies have been initiated to explore the endogenous factors responsible for resistance to heat stress. In preliminary studies of the role of plant hormones and growth regulators, it was observed that there was a 10-fold increase in the production of gibberellins (GA) in shoots on increasing temperature from 20 to 30° C under a 12-hour daylight regime. The GA level increased 5-fold when temperature was held constant at 20° C, but the daylength was increased from 12 to 18 hours. Abscisic acid (ABA) levels remained constant at both 20 and 30° C and at 12 and 18-hour photoperiods (Fig. 7).

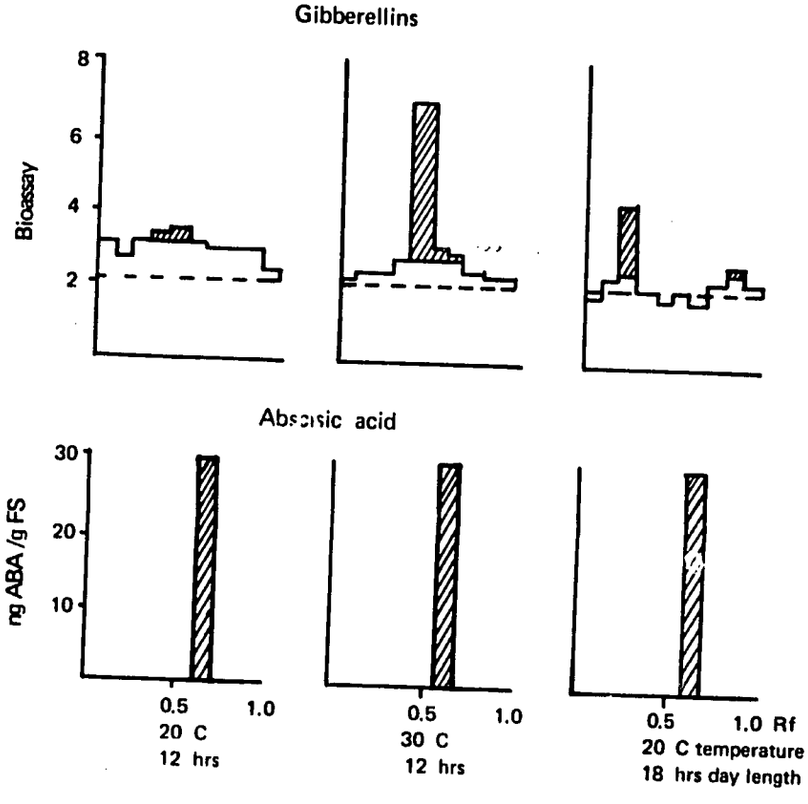



**Fig. 7 — Gibberellins separated by paper chromatography and assayed by lettuce hypocotyl. Cross-hatching indicates significance at 1 percent level of probability. Abscisic acid assay by gas chromatography.**

The interaction of N supply and the GA and ABA content of shoots (*S. tuberosum*) has been examined. With the interruption of N supply, the level of GA in shoots decreased and the level of ABA increased. Restoring the N supply reversed the GA/ABA ratio. It was also noted that when high rates of N were supplied after tuberization, tuber growth was inhibited and stolons formed at the apex of tubers. Interruptions of N supplies initiated tuberization again (secondary growth).

The capacity of leaves of four clones to tolerate high temperature (38° C day ; 32° C night) was studied as part of thesis research supported by a contract at Cornell University. Clone 1-4 of *S. acaule* and clone 10-10 of *S. chacoense* were very sensitive to high temperature. Clones 10-3 of *S. chacoense* appeared intermediate in sensitivity and clone 11-5 of *S. chacoense* was tolerant. Neither the rate of photosynthesis (monitored by infra-red $CO_2$ analyzer in controlled temperature leaf chambers), transpiration, nor cell membrane permeability under heat stress were correlated with heat sensitivity. However, there appeared to be a correlation between respiration rate and sensibility to heat (Fig. 8).

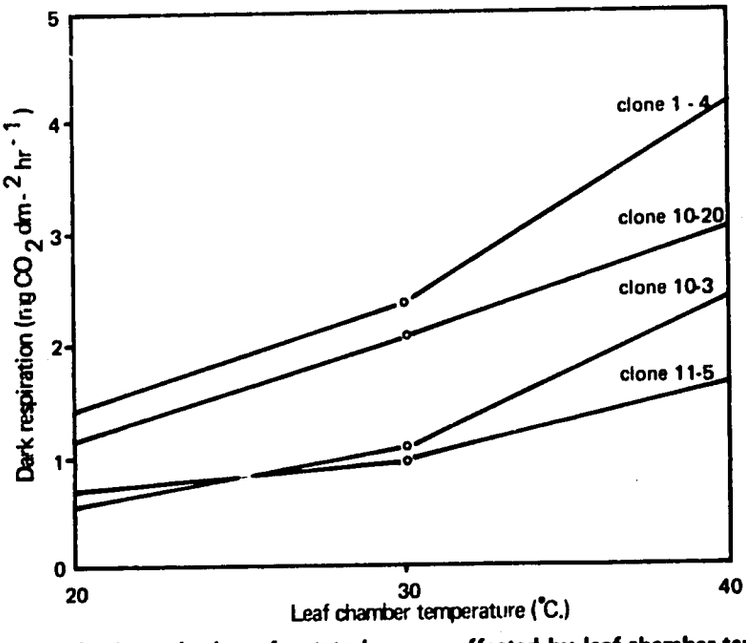



**Fig. 8 — Dark respiration of potato leaves as affected by leaf chamber temperature 20 minutes prior to measurement. Clones 10-3, 10-10, and 11-5 are *Solanum chacoense*; clone 1-4 is *S. acaule*.**

In breeding for heat tolerance at Cornell, crosses of heat-tolerant clones produced 764 seedlings out of 1,960 which tuberized under conditions of heat stress: 32° C day; 24° C night. From the seedling families that tuberized, heat-tolerant clones (those that produced the largest tubers) and non-heat tolerant clones (those that produced the smallest tubers) were identified. Because of the bias introduced by comparing progeny from different size tubers, plants derived from cuttings were evaluated under heat stress conditions. The heat tolerance index of heat-tolerant clones was one-third higher than non-heat tolerant clones. There were no differences in growth rate among the clones.

In a separate experiment, heat-tolerant clones did not differ in photoperiod response from non-heat tolerant clones in their capacity to tuberize. This suggests the independence of heat tolerance from photoperiod response (Fig. 9). Preliminary studies have also shown a differential increase in free proline in leaves subjected to a continuous temperature of 37° C.

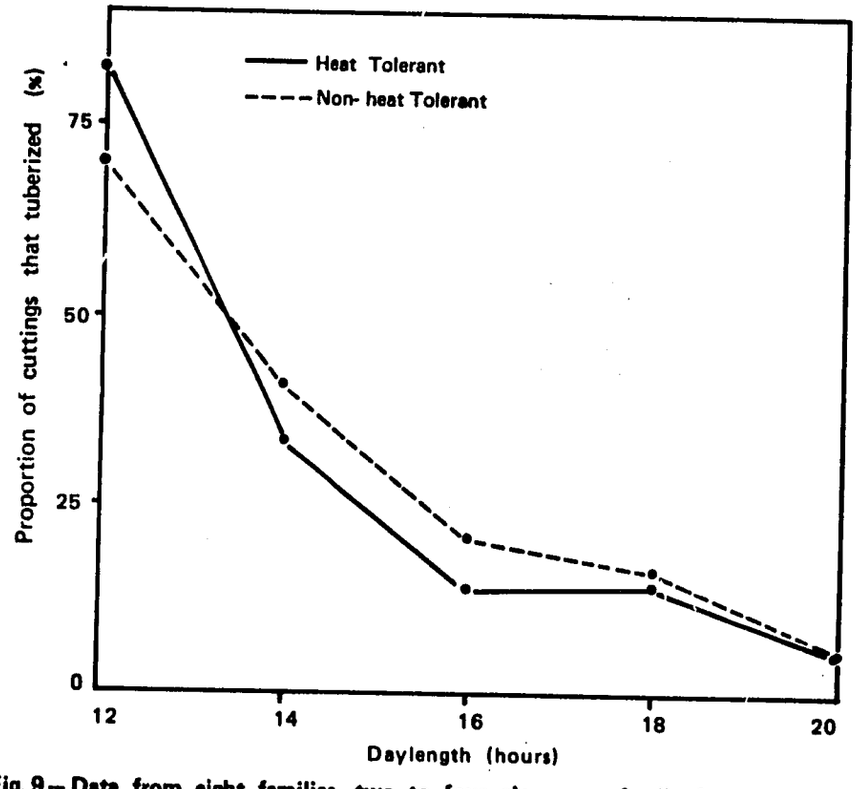



**Fig. 9 — Data from eight families, two to four clones per family for each heat-tolerant category. Each point represents from 41 to 114 cuttings inspected.**

## Cold Tolerance

Coupled with favorable progress in breeding clones resistant to -4° C; is the increasing understanding of the anatomical and physiological basis of frost resistance. In research at the University of Minnesota, supported in part by contractual arrangements with CIP, ultrastructural differences in leaf cells of potatoes were examined in relation to their frost resistance.

A four-fold increase in osmiophilic globuli in chloroplasts, from 1,130 to 4,217 per 100 chloroplasts, occurred following cold acclimation of the frost resistant species, *S. acaule*, to -9° C. In contrast, in "Red Pontiac", a frost-susceptible *S. tuberosum* variety which cannot be acclimated, the globuli increased from 563 to 872 per 100 chloroplasts. Apparently lipid accumulation is associated with exposure to freezing temperatures. The disappearance of starch grains in the chloroplasts of *S. acaule*, while those of *S. tuberosum* "Red Pontiac" remained intact, suggests a possible protective effect of soluble sugars against freezing injury in these sensitive organelles.

In obervations of leaf anatomy, nine hardy species (killing temperature -4° C and below) had two layers of palisade leaf parenchyma, while 19 non-hardy species (killing temperature -2.5 to -3.5° C) had only one layer. The leaves of hardy plants were generally thicker with the palisade layers occupying more than 65 percent of the total leaf thickness. The leaf palisade of non-hardy species comprised less than 50 percent of the total leaf cross-section.

The walls of leaf mesophyll cells of *S. acaule* were significantly thicker than comparable walls of the *S. tuberosum* cultivar (Table 26). The number of stomata, relative to the total number of cells, was three times greater in the hardy than in the non-hardy species.

**Table 26 – The cell wall thickness of the leaf mesophyll cells of two potato species.**

| Species and type of cell | Mean cell wall thickness (mm) |
|---|---|
| *Solanum acaule* | |
| Palisade | 205.031 |
| Spongy | 226.029 |
| *S. tuberosum* "Red Pontiac" | |
| Palisade | 107.315 |
| Spongy | 123.414 |

Note: All means are significant at the 5 percent confidence level according to Duncan's Multiple Range Test. (After Bot. Gaz. 138(3):276-285. 1977)

In another study at the University of Minnesota, the frost-killing temperatures of 60 tuber-bearing species were determined in material not previously acclimated. Selections of *S. acaule* were resistant to -6.5° C. The average killing temperature of the 60 species was -3.5° C, range -2.5 to -6.5° C.

## Photoperiod

Potatoes are grown commercially under 19-hour days as well as 10-hour days. While some clones are known to tuberize under a range of photoperiods, daylength is generally a critical factor in the control of tuberization. Because of the excellent controlled environment facilities in the North Carolina State University (NCSU) Phytotron, studies of the inheritance of tuber initiation as influenced by photoperiod was carried out under contract research in the Southeastern Plant Environment Laboratories at NCSU.

Three day-neutral *tuberosum*, and one day-neutral and four short-day *andigena* clones, were used as parents. Eight genetic sets of parental, filial, and back-cross generations were developed. Tuber initiation was evaluated in growth chambers with daylengths of 11, 13 and 15 hours, a range of photoperiods normally experienced in countries of the equatorial belt.

$F_1$ generation means from short-day X day-neutral crosses showed complete dominance of the short-day (late tuber initiation) over the day-neutral reaction (early tuber initiation). $F_1$ generation means from day-neutral X day-neutral and short-day X short-day crosses showed either no dominance or a tendency toward the short-day parent. A variable degree of parental heterozygosity for the loci controlling tuber initiation is indicated with the short-day clones showing the greatest genetic variability. Tuber initiation appears to be under the control of both major and minor genes. General combining ability values of 90 percent at 11 hours and 55 percent at 15 hours of daylength were estimated. Increases in daylength had the effect of delaying tuber initiation.

In contract research at Cornell University, a cutting technique has been developed to permit rapid screening to evaluate "tuberization stimulus" under unfavorable photoperiods. Using this technique, clones capable of tuberizing under continuous light have been identified.

To test whether there is a partial maternal inheritance of the photoperiod response, a clone capable of tuberizing under continuous light and a clone that required short days (usually 12 hours or less) were each selfed and also crossed in both directions. Thirty-two seedlings from each of the resulting four populations were grown under continuous light. Cuttings were taken and examined for ability to tuberize and the parent plants then were placed under 22 hours of light. Another crop of cuttings was taken and the photoperiod was shortened to 20 hours. The process was repeated until plants had been exposed to 18, 16, 14 and 12 hour days (Table 27). Yields of plants exposed to 20, 14 and 8 hour photoperiods also were measured (Table 28).

**Table 27 — Effects of pedigree and of photoperiod, prior to cutting, on percentage of cuttings forming tubers**

| Pedigree | Percentage cuttings forming tubers | | | | | | |
|---|---|---|---|---|---|---|---|
| | 24 | 22 | 20 | 18 | 16 | 14 | 12 * |
| Short CPP X Short CPP ** | 0 | 0 | 0 | 0 | 0 | 0 | 29.7 |
| Short CPP X Long CPP | 0.5 | 1.0 | 4.2 | 8.3 | 4.7 | 18.2 | 58.9 |
| Long CPP X Short CPP | 7.8 | 2.6 | 4.7 | 8.3 | 7.8 | 30.2 | 92.7 |
| Long CPP X Long CPP | 19.8 | 22.4 | 33.3 | 48.4 | 54.2 | 77.6 | 87.0 |

* Photoperiod hours prior to taking cuttings.
** CPP = Critical Photoperiod.

**Table 28 — Effects of pedigree and photoperiod on tuber yields**

| Pedigree | Yield, gm per plant | | |
|---|---|---|---|
| | 20 hr. | 14 hr. | 8 hr. |
| Short CPP X Short CPP * | 0 | 0.3 | 22.5 |
| Short CPP X Long CPP | 19.9 | 62.8 | 89.1 |
| Long CPP X Short CPP | 35.1 | 83.4 | 110.8 |
| Long CPP X Long CPP | 97.6 | 137.6 | 93.1 |

* CPP = Critical Photoperiod.

As expected the population derived from selfing the clone with a long critical photoperiod, had the greatest capacity to tuberize under long photoperiods. The population derived from selfing the short-day clone tuberized most efficiently under short photoperiods while populations from crosses were intermediate.

The reciprocal crosses showed a clear maternal influence. When the clone with the long critical photoperiod was the maternal parent, tuberization and yield were significantly greater under continuous light than in the population from the reciprocal cross. Repeating the experiment with 144 seedlings from each pedigree, under greenhouse conditions, confirmed the results of the growth chamber experiments.

**Drought Resistance**

Attention has been focused on field methods of measuring drought stress through studies affiliated with the Research Station for Arable Farming in Wageningen, the Netherlands. Extensive trials have been conducted at CIP on the arid coastal desert of Peru where average annual precipitation is 10 mm.

Each of several methods for measuring water stress had deficiencies, necessitating an integration of data for a meaningful assessment of drought resistance in the field. Pressure chamber data taken in early morning or late afternoon, together with data on the infiltration of leaves with oils of varying viscosity taken during early afternoon, permitted the following interpretations: a) small increases in pressure chamber values at increasing soil suction (indicating an efficient root

system), together with open stomata (determined by [illegible]), are indicators of drought tolerance; b) a large increase in water potential and open stomata are suggestive of low water conservation and early senescence; while, c) a small decrease in water potential and closed stomates for a prolonged period during a day might be favorable for the maturation of a late variety under irregular water supply.

## Agronomic Studies

Studies were continued at La Molina (coastal desert), San Ramon (high jungle) and Yurimaguas (low jungle) in the use of mulch to modify soil temperatures. An example of the ameliorating influence of mulch on soil temperature is shown in Fig. 10.

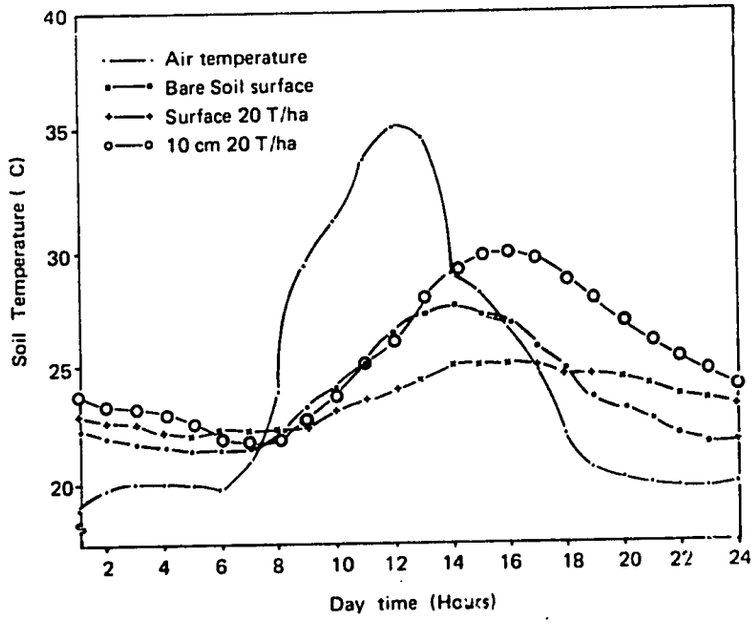



**Fig. 10 – Effect of grass mulch levels on soil temperature, La Molina, February, 1977.**

An associated cropping study was conducted in the Mantaro Valley (3,300 m) to investigate its possible economic advantage. Beds 1.2 m wide were planted with one row of potatoes and the associated crop planted in the same bed (Table 29).

**Table 29 — Potato yields and income for different associations of crops, with and without fertilizer**

| Crop association * | Yield t/ha — Fertilizer applied/ha: 0 | 160:200:200 | Gross income, $ US/ha: No fertilizer | Fertilized |
|---|---|---|---|---|
| Potato | 21.2 | 43.3 | 2,466.00 | 4,966.00 |
| Potato-corn | 10.5 | 25.1 | 1,467.00 | 3,506.00 |
| Potato-bean | 12.4 | 25.5 | 1,677.00 | 3,446.00 |
| Potato-pea | 12.7 | 32.7 | 1,520.00 | 3,913.00 |
| Potato-quinoa | 9.5 | 18.3 | 1,409.00 | 2,714.00 |
| Corn | 2.9 | 7.5 | 446.00 | 1,154.00 |
| Bean | 1.2 | 1.8 | 462.00 | 392.00 |
| Peas | 0.8 | 1.1 | 308.00 | 423.00 |
| Quinoa | 1.0 | 2.1 | 538.00 | 1,131.00 |

* Bean = *Vicia faba*; Pea = *Pisum sativa*; Quinoa = *Chenopodium quinoa*.

A number of field fertilizer trials were undertaken in 1977 at sites in Peru, representing divergent ecological zones. In these trials it was usual to include a control in which no fertilizer was applied. An example of a trial involving various levels of nitrogen, while phosphorus and potash were constant, is presented in Table 30.

**Table 30 — Yield response of t/ha to varying nitrogen application at a highland site, Huancayo (3,300 m)**

| Varieties | Fertilizer applied (kg/ha): 0:0:0 | 0:200:200 | 80:200:200 | 160:200:200 | 240:200:200 | Mean |
|---|---|---|---|---|---|---|
| T. Condemayta | 29.2 | 30.8 | 37.9 | 45.5 | 38.2 | 36.3 |
| Mi Peru | 26.7 | 36.2 | 42.0 | 54.1 | 43.6 | 40.5 |
| Yungay | 25.8 | 35.8 | 42.4 | 45.9 | 44.1 | 38.8 |
| Mariva | 25.7 | 32.7 | 34.3 | 38.2 | 34.4 | 33.1 |
| Cuzco | 25.0 | 38.4 | 44.5 | 49.8 | 47.8 | 41.1 |
| Antarqui | 22.3 | 27.8 | 30.5 | 34.5 | 31.3 | 29.3 |
| N578-4 | 21.1 | 23.5 | 37.0 | 39.8 | 38.2 | 31.9 |
| Revolucion | 18.5 | 35.2 | 41.6 | 46.5 | 42.3 | 36.8 |
| 65-ZA-5 | 13.5 | 23.8 | 29.1 | 38.5 | 27.5 | 26.5 |
| Rosita | 12.4 | 24.3 | 30.8 | 36.1 | 33.7 | 27.5 |
| MEAN | 22.0 | 30.8 | 37.0 | 42.9 | 38.1 | 34.2 |

In a trial involving varying levels of a recommended fertilizer (160:200:200) application, the differential efficiency of cultivars in utilizing fertilizer is apparent (Table 31). It was also evident that adaptation to the experimental sites influenced yield (Tables 30 and 31).

**Table 31 – Yield response to varying levels of fertilizer application at a high jungle site, San Ramon (800 m)**

| Varieties | Fertilizer formulation (kg/ha) | | | | |
|---|---|---|---|---|---|
| | 0:0:0 | 80:100:100 | 160:200:200 | 240:300:300 | Mean |
| Antarqui | 15.8 | 27.5 | 32.0 | 28.4 | 25.9 |
| Rosita | 14.1 | 17.8 | 24.9 | 19.0 | 19.0 |
| Cuzco | 14.0 | 22.5 | 26.1 | 26.5 | 22.3 |
| Mariva | 13.8 | 20.9 | 30.0 | 28.8 | 23.4 |
| Mi Peru | 10.0 | 17.1 | 19.2 | 15.0 | 15.3 |
| M1295 | 9.6 | 14.0 | 15.0 | 17.0 | 14.1 |
| Yungay | 9.3 | 17.4 | 28.2 | 27.3 | 20.6 |
| Revolucion | 8.8 | 19.6 | 17.3 | 16.9 | 15.7 |
| T. Condemayta | 7.3 | 6.6 | 11.4 | 9.5 | 8.7 |
| N578-4 | 5.3 | 9.9 | 14.0 | 13.6 | 10.7 |
| MEAN | 10.8 | 17.3 | 21.8 | 20.3 | 17.6 |

In a related study, the effect of different management practices upon soil erosion and run-off under different cropping regimes was measured. Two sites were involved, one with 25 percent slope, rainfall 480 mm, on an inceptisol soil over a micaceous schist; the other with a 30 percent slope, rainfall 2,154 mm, on an entisol developed over colluvial-alluvial material.

The importance of management practices was clearly demonstrated at the San Ramon site with the higher (2,154 mm) annual rainfall (Table 32).

**Table 32 – Loss of water, soil and nutrients under different management practices at San Ramon during one year**

| Treatment | Run-off $m^3$/ha | Erosion MT/ha | Nutrients eroded (kg/ha) Total N | P | K | Ca | Mg |
|---|---|---|---|---|---|---|---|
| 1. Bare soil | 2,221 | 148 | 115 | 3.5 | 19 | 310 | 7.3 |
| 2. Fallowed and burned + corn + bean + potato (rows with 30° slope) | 1,972 | 119 | 106 | 3.6 | 14 | 360 | 5.5 |
| 3. Forage (*Centrocema pubens*) | 735 | 1.3 | 0.6 | 0.0 | 0.2 | 3 | 0.1 |
| 4. Fallow + corn + bean + potato (mulch with minimum tillage) (rows with 30° slope) | 1,358 | 46 | 38 | 1.4 | 6.0 | 122 | 2.6 |

# DEVELOPMENT OF POST-HARVEST TECHNOLOGY AND IMPROVEMENT OF NUTRITIONAL QUALITY

## Storage

Physical data relating to the insulating qualities of a wide range of structural materials are readily available. This information has been used in designing stores for teaching and demonstration purposes at CIP. During 1977, two 35-ton storages for market potatoes, one of wood and the other of adobe, were constructed. At the end of 1977 the storages had been filled and appropiate recording instruments installed to monitor the storage environment. A low-cost, six to seven ton prototype storage with plastic exterior walls was also constructed to store seed potatoes under diffuse light. A small refrigerated storage for conditions of high ambient temperature at San Ramon is being designed.

**Prototype storage with plastic exterior walls for storing seed potatoes under diffuse light.**

Collection point for potatoes. Farmers bring in their potatoes and sort them for buyer's inspection.

Filling an improved type of potato pit. The wooden chimney has openings in the corners and is placed in the center of the (round) pit. Pit capacity is 1 ton.

Building improved type potato storages for small scale farmers. Capacity is 2 tons.

A practical study aimed at evaluating the technical and economic feasibility of ware potato storage on small farms in Kenya was started in 1977. Traditionally, three storage systems have been used in Kenya: 1) earth pits for seed potatoes; 2) piles in farm buildings; and, 3) bags (traders storage). No reliable data, on storage losses incurred in these systems has been previously available.

As a result, a wooden store was designed and tested in cooperation with the Ministry of Agriculture and the Faculty of Agriculture, University of Nairobi (Table 33).

**Table 33 — Percent storage loss of Kerr's Pink potatoes in wooden store piles in farm houses at three Kenya sites**

| Store type | Location | Two months storage losses | | | | Four months storage losses | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Rotten | Sprouts | Weight loss * | Total | Rotten | Sprouts | Weight loss | Total |
| Wooden stores | Ngechi | 1.1 | 0.2 | 5.5 | 6.8 | 2.6 | 1.6 | 12.3 | 16** |
| | Meru | 0.4 | 0.0 | 4.2 | 4.6 | 0.3 | 4.6 | 0.6 | 5 |
| | Molo | 0.1 | 0.0 | 4.7 | 4.8 | 0.3 | 0.8 | 5.2 | 6** |
| | Average | 0.5 | 0.1 | 4.8 | 5.4 | 1.1 | 2.3 | 6.0 | 9 |
| Piles in farm houses | Ngechi | 0.6 | 0.4 | 5.1 | 6.0 | 1.8 | 2.9 | 14.2 | 18** |
| | Meru | 2.5 | 0.0 | 4.8 | 7.3 | 0.6 | 3.3 | 14.0 | 18 |
| | Molo | 0.1 | 0.0 | 2.6 | 2.8 | 0.5 | 2.0 | 13.2 | 15** |
| | Average | 1.1 | 0.1 | 4.2 | 5.4 | 1.0 | 2.7 | 13.8 | 17 |

* Weight loss due to dehydration, respiration and non-explained losses.
** Treated with sprout suppressant.

Observations in Kenya during the first season showed that earthen pits were unsatisfactory for ware storage. Bag storage was less suitable than storage in piles. Bag and pit storage studies were, therefore, discontinued. For periods up to two months, pile stores were more

economical than wooden stores. For storage periods longer than two months returns to investment were about the same for the low-cost wooden store as for a medium size (150-ton capacity) commercial potato store. The higher storage losses at Ngechi (2,100 m) than at Meru (2,300 m) and Molo (2,600 m) were attributed to consistently higher night temperatures at Ngechi during the period February to June, 1977.

## Processing

A study was continued throughout the year on small-scale processing of potatoes. In addition to designing and evaluating various dehydration methods, field studies of potato processing technology on small farms in the Mantaro Valley region of Peru were carried out by CIP's Social Science Unit. The contributions of this group are presented elsewhere in this Annual Report.

A number of conditions must be met to obtain satisfactory solar dehydration of potato products: 1) The water in the product must trap sufficient calories to vaporize it. Calories trapped by a black surface or air will not evaporate water from the product unless such calories are reradiated to the product water. 2) The rate of diffusion of water from the center to the surface, and from the surface of the product, is determined by the steepness of the diffusion gradients. This is a function of the temperature and relative humidity of the air in contact with the product, as well as the shape and physiological nature of the product. 3) Excessive heat must be avoided during drying to prevent discoloration of the product.

Various configurations of "black box" solar dryers have been tested. A one-meter square wooden or adobe box with sides 10-20 cm high, covered with flexible 8-mil plastic, with provision for ventilation to allow moisture escape, was a satisfactory low-cost dehydration module. Square, "V" and hemispheric notched floor surfaces to enhance trapping solar radiation did not justify the extra construction effort.

An unpolished aluminum surface was 10° C hotter, and a reflecti aluminum surface was 10° C cooler than the black-painted floor surfac of a dehydration module. Air temperatures of 75-95° C and surfac temperatures of 95-105° C are indices of attainable temperatures in "black box" module.

Adequate drying, without discoloration, was obtained with 1 mm-thicl shreds exposed for one day at a temperature of 55° C (altitude 3,300 m). Air movement to permit moisture escape and to maintain a temperature below 70° C was provided by raising the plastic top o the dryer 2-5 cm or by small ventilation holes in the bottom and side of the box. At temperatures above 70° C, particularly nearing the completion of drying, brown discoloration and unpleasant flavors developed. Satisfactory drying of products other than potatoes, such as onions, yucca and sweet potatoes, offers a wide scope for black box technology in Andean food processing.

## Nutritional Studies

A wide range of routine analyses was carried out during the year in support of a variety of research projects. Included were analyses of catalase activity; total and reducing sugars; vitamines $B_1$, riboflavin, niacin and C; total protein; relative nutritive values; available methionine; minerals – iron, copper, magnesium, manganese, potassium, zinc and iodine; glycoalkaloids; and, dry matter. As an example of routine analyses, the dry matter, total protein and reducing sugar levels determined for 12 commercial Peruvian varieties were: dry matter, mean 22.96 percent, range 1.27 – 27.98 percent; total protein, mean 7.70 percent, range 6.13 – 11.69 percent; and, reducing sugars, mean 0.36 mg/percent, range 0.15 – 0.89 mg/percent.

Similar analyses of 249 samples involving seven species are presented in Table 34. The range in percent total protein, on a dry matter basis, was 4.5 – 14.5 percent, average 7.87 percent. Relative nutritive values were lower for raw potatoes than for cooked potatoes. In a study of six varieties in storage at 5° C for up to three months, there was a gradual increase in relative nutritive value up to 45 days followed by a decline.

**Table 34 – Relative distribution of dry matter, total protein, available methionine and relative nutritive values in 249 potato clones from the CIP germ plasm collection**

| Species | No. samples | Dry matter % | Total protein g/100 g | Available methionine g/16 g N | Relative* nutritive value |
|---|---|---|---|---|---|
| *S. tbr* ssp. *andigena* | 137 | 26.9 | 7.4 | 1.6 | 78.5 |
| *S. chaucha* | 27 | 26.0 | 7.7 | 1.6 | 78.5 |
| *S. stenotomum* | 15 | 28.5 | 10.0 | 1.4 | 79.0 |
| *S. phureja* | 7 | 26.9 | 9.5 | 1.4 | 77.3 |
| *S. curtilobum* | 10 | 26.0 | 9.9 | 1.1 | 56.1 |
| *S. ajanhuiri* | 3 | 26.7 | 9.5 | 1.3 | 75.0 |
| *S. tuberosum* | 50 | 22.8 | 10.1 | 1.3 | 88.6 |

* Nutritive value relative to casein = 100 as determined by microbiological assay (*Streptococcus zymogenese*) on raw potatoes.

# SEED PRODUCTION RESEARCH FOR DEVELOPING COUNTRIES

The CIP potato cell and tissue culture program has the following objectives: a) to maintain potato germ plasm in clonal form for prolonged periods free of pathogens; b) to facilitate the international transfer of valuable potato clones; c) to rapidly multiply clonal material in a disease free condition; and, d) to adapt and develop new areas of research and application.

## Tissue Culture Research

The multi-meristem culture technique has been successfully employed for the rapid, *in vitro* multiplication (up to 100-fold) of the species *andigena* (4x), *chaucha* (3x), *juzepchukii* (3x) and *curtilobum* (5x). Shoot proliferation was hastened with gibberellic acid on "organogenic calluses" induced by cytokinin and auxin. To induce profuse shoot development in *tuberosum* (4x) varieties, initial shoot-tip explants were first allowed to elongate their leaves and axes slightly with the addition of a low level of gibberellic acid and a relatively high level of auxin. Thereafter, a highly branched culture with very little or no callus was produced under the influence of low cytokinin and high gibberellic acid. At present 40 of 50 different pathogen-tested clones have been processed through the multi-meristem system. During 1977, 132 aseptic multi-meristem cultures representing 71 clones were sent to 10 countries.

A minimum growth storage technique has been developed for intermediate term storage requiring one transfer per year. Nodal cuttings from plantlets derived from multi-meristem cultures are maintained at 4-5° C, under low light, on media with low levels of growth inhibitors and relatively high sugar content. A reversal of these conditions enhances *in vitro* growth. Of interest is the differential behavior of *andigena* and *tuberosum* clones, adg clones being more subject to injury

from relatively high temperatures and high levels of growth inhibitors than tbr clones. A temperature of 6° C, without growth inhibitors, was repressive to the growth of tbr clones, but not to adg clones. Recently 44 different pathogen-free clones, three or four test-tube cultures of each, have been placed in minimum growth storage conditions for observation during 1978.

There is an element of concern with regard to the karyological instability of *in vitro* cultures due to euploidy, aneuploidy, chromosomal translocations, and possibly, mutations. Experiments are continuing to evaluate the stability of varietal characteristics of two clones. Virus-infected plants were processed through single and multi-meristem culture systems. The single culture approach gives rise to a single plant directly, while many plantlets (multi-meristem) develop on an "organogenic callus" derived from a single shoot-tip. Virus-free plants and plants still containing viruses (PVX, PVX + PVY) were regenerated, potted and allowed to tuberize. These tubers, together with tubers of the original infected "mother" plants and tubers of plants naturally free, were potted again to produce second generation tubers. These were used to compare electrophoretic patterns of total soluble tuber proteins and esterases.

No changes were observed in protein and esterase electrophoretic patterns, due to either the tissue culture system or the presence or absence of viruses. Taxonomic-cytological studies, as well as evaluation of cultures being stored for intermediate periods are under continuing study.

The possibilities of shipping small, aseptic tubers grown *in vitro* to developing countries, and the use of *in vitro* tuberization to study certain basic high-temperature stress problems, have encouraged studies of tuberization in culture. To present, nodes excised from plantlets arising in multi-meristem cultures have been the most convenient source of explant material for the production of a large number of tubers in a continuous fashion. Most clones have required a medium rich in sugar and supplemented with high concentration of chlorocholin-chloride (CCC).

## Stem Cutting Propagation

The use of stem cutting and related techniques to rapidly multiply potatoes under disease-free conditions was established as a routine procedure in 1976. The use of a liquid mixture of IBA and NAA in 30 percent ethanol has effectively increased rooting of cuttings while inhibiting tuberization. The rate of propagation from tubers was increased three to four-fold by making stem and stolon cuttings from the tubers of certain slow growing clones.

An adaptation of a published "leaf-node cutting" technique is being developed. This system involves the induction of tubers on stem segments containing an axillary bud and its subtending leaf excised from the stems of senescent plants. Thus a plant with 10 to 15 nodes on each of five stems will provide 50-75 leaf-node cuttings. When planted in coarse sand under short day conditions and relatively low temperature these cuttings would, potentially, produce 50-75 tubers.

In another technique being evaluated, secondary sprouts were generated on tubers several weeks after removal of 3 to 5 cm primary sprouts and immersion of the tubers in 2.0 ppm gibberellic acid. Excised sprouts were allowed to root on wet filter paper before being planted in pots or trays.

## Production of Pathogen-free Seed

The CIP program for virus eradication in potatoes consists of a number of stages referred to as "Generations". Generation "O" has been divided into steps: Step 1, virus detection tests; Step 2, meristem culture following thermotherapy and regeneration of plants from culture; and, Step 3, confirmation of the virus-free status of regenerated plants in insect-proof greenhouses. If non-infected material is identified in Step 1, the plant is moved to Step 3, bypassing Step 2.

The effectiveness of eradication depends upon the system employed (Table 35). The application of high temperature to *in vitro* nodal cuttings derived from multi-meristem has been effective in the eradication of PVX and PVS. More recently the enzyme-linked immunosorbent assay (ELISA) method is being evaluated as a means of detecting viruses in *in vitro* cultures.

**Table 35 — Percent virus eradication by means of different meristem-tissue culture systems and temperature regimes**

| | | Day/night temp (°C) and duration (wks) | | | | | | Final | Tissue |
|---|---|---|---|---|---|---|---|---|---|
| | | 24° / 28° | | 37° / 30-32° | | | | eradication | culture |
| Clone | Virus | 2 | 8 | 1 | 2 | 4 | 8 | percent | system * |
| 1 | PVX | 0 | 0 | – | – | 0 | 100 | 100 | A |
| | PVX | 50 | – | – | – | – | – | 50 | B |
| | PVX | 0 | 0 | – | – | 0 | 0 | 0 | C |
| 2 | PVX | – | – | – | 100 | – | – | 100 | D |
| 3 | PVX | 0 | 0 | – | 0 | 70 | – | 70 | A |
| | PVX | – | – | – | 75 | – | – | 75 | F |
| 4 | PVS | – | – | – | 0 | 70 | – | 70 | E |
| 5 | PVS | – | – | 0 | 0 | – | 30 | 30 | E |
| | PVS | – | – | 30 | – | – | – | 30 | D |
| | PVS | – | – | – | – | 80 | – | 80 | A |

* A : Thermotherapy *in vitro* of tip and nodal cuttings from multi-meristem cultures.
B : Tip and nodal cuttings from mulit-meristem cultures.
C : Multi-meristem culture only.
D : Single meristem, fast growth cultures from heat-treated plants.
E : Single and multi-meristem cultures from heat-treated plants.
F : Single meristem, fast growth cultures from heat-treated etiolated sprouts.

Commonly, the development of an isolated meristem tip into a plantlet takes up to three months. By weekly transfers to fresh semi-solid medium with a high level of GA, plantlets four to five cm in height can be produced in three to four weeks. This technique not only accelerates the growth several-fold but also tends to favor virus eradication.

During 1977 approximately 50 clones have been processed through meristem culture, usually following thermotherapy. Of these, 43 have been grown in pots and moved to the greenhouse for virus retest. Thirty-three clones have entered Step 3 after meristem culture and plant regeneration, 24 of which were free of viruses and have entered Generation I. In addition, 27 clones entered Generation I directly being found free in Step 1 and confirmed in Step 3, Generation "O".

Five Generations are involved in the maintenance and progressive multiplication of pathogen-free seed. Generation I involves the maintenance of nuclear stock derived from Generation O. In Generation II pathogen-tested clones are produced for export to national programs for local increase or testing. Generations III, IV and V are for the progressive increase of low-virus seed for routine CIP field research.

Generation I : At present 88 clones are being maintained, 44 as *in vitro* multi-meristem cultures and 44 as both multi-meristem cultures and plants. Clones for which there is limited use are held only as multi-meristem cultures.

Generation II : Thirty-six varieties were multiplied for export. Also included were 201 tuber families, produced from true seed, which were sent to 10 developing countries for evaluation for tropical adaptation, resistance to late blight and for frost resistance. From pathogen-tested clones of this Generation, 4,430 stem cuttings were produced for the Peruvian National Potato Program and 4,500 for CIP scientists.

Generations III, IV and V: During the 1976-77 crop year, about 16.5 metric tons of seed were distributed to CIP scientists, while 2.5 tons were replanted to produce the 1977-78 crop. In addition, over 5,000 stem cuttings were produced from Generation III plants for CIP use. A summary of material exported during the year is presented in Table 36.

**Table 36 – Pathogen-tested materials exported during 1977**

| | Tubers | Multi-meristem | Tuber families | No. Cuttings | Botanical seed lots |
|---|---|---|---|---|---|
| Region I | 20 | – | 51 | 4,430 | 131 |
| Region II | 17 | 7 | 50 | – | 95 |
| Region III | 2 | 8 | – | – | – |
| Region IV | 6 | 8 | 36 | – | 48 |
| Region V | – | – | 21 | – | – |
| Region VI | – | – | 6 | – | – |
| Region VII | 8 | 26 | 42 | – | – |
| Europe | 10 | 3 | – | – | 205 |
| North America | – | 3 | – | – | 20 |
| Japan | – | – | – | – | 20 |
| Australia | – | 16 | – | – | – |
| TOTAL | 63 | 71 | 206 | 4,430 | 519 |

## Region II

In Honduras and Costa Rica long-term seed production programs have been initiated. With four tons of Super Elite seed from the Netherlands, Honduras has produced 25 tons of low virus seed. This first year of production has served as training for local scientists and farmers. In Costa Rica, selected clones and varieties are being multiplied from stem cuttings. New land facilities are being organized to develop a full-scale seed project in 1978. A plan to receive and multiply méristems of Rosita and Atzimba varieties has been initiated jointly among CIP, the University of Costa Rica and the Ministry of Agriculture. The University has the facilities to carry out the initial propagation of meristem material which is then transferred to the greenhouse to produce tubers and mother plants. This material will become the basic stock for the national seed project.

A problem in rooting cuttings was encountered at Turrialba. This was traced to a nutrient deficiency in the medium. A new medium of coarse sand and bagasse, and irrigation with Hoagland's solution has produced excellent results. Upon transplanting rooted cuttings directly to the field at Turrialba, 90 percent died. However, a system has now been developed which uses paper cups for growing the cuttings and these are transplanted directly to the field. The problem has been resolved.

## Region III

Seed schemes are being developed in Kenya and Zambia, with some initial contacts in Malawi, Southern Sudan and Lesotho.

In Kenya, the scheme proposed will involve CIP, the Kenya Seed Inspection Service, Kenya Seed Company (a commercial organization) and the Potato Research Section of the Ministry of Agriculture. The basic materials will be provided by the Research Section.

In Zambia, a seed production scheme has already been started and CIP's input will be limited to supplying materials as required, periodic advisory visits and training of personnel.

## Region IV

### Turkey

The stem cutting technology has been introduced to accelerate the production of first year basic seed. After solving initial problems, the production of stem cuttings from mother plants has been established. Some virus-tested clones imported from CIP as multi-meristem have been grown in Turkey.

### Tunisia

A simplified production scheme for low virus-content seed has been started in Tunisia. This aims to provide seed for the autumn crop sown in August when imported seed of the right physiological age is not available. Seventy-five tons were produced in 1977 which have already been distributed to farmers and planted. The vigor and number of stems per unit area of this seed is far superior to farmers' seed. Depending on the time at which haulms were destroyed, the virus content has varied from four to 14 percent.

## Region V

### Pakistan

A cooperative project to develop seed production in the autumn season in the plains has been started with the Punjab Government. This will support the overall national program, particularly with facilities to develop a basic seed area in the Kaghan Valley. This project is being aided by a bilateral contract.

## Region VI

### India

India already has the most advanced seed program in tropical countries and new techniques are not envisaged in the near future. The program however will serve as an excellent training ground for other developing country personnel.

## Nepal

The main objective of CIP's involvement is to assist the development of a strong seed program to amplify the existing traditional systems of seed production. It will provide a means for disseminating varieties and clones already identified as having improved yield and disease resistances.

Preliminary trials for introducing rapid multiplication by the stem cutting technique showed that during the dry season rooting was difficult, but by providing sufficient shade and humidity rooting was accomplished. Up to 150 cuttings could be taken from some mother plants. In transportation to the high altitude station, a high percentage of rooted cuttings survived the journey.

Trials were made of a sprout cutting method. The advantages of this method are that all cuttings are available simultaneously, no mother plants have to be raised and greenhouse space is not required. The results were encouraging, providing that temperature and humidity were adjusted as in the case of the stem cutting method.

From the pathogen-tested seed produced by CIP - Lima, 17 new clones have been introduced. It had been hoped that *S. andigena* x *tuberosum* crosses would do well in Nepal. This has been realized and Mariva, a Peruvian variety, not only produced an outstanding yield, but its tuber characteristics almost exactly matched the preferred local "round red" variety. With its additional late blight and virus resistance it might well replace the local variety, provided that it produces equally well on the plains.

## Region VII

Trial shipments of meristem tissue cultures of heat-tolerant material was sent to Indonesia and the Philippines. The cultures shipped to Indonesia were etiolated at the end of the three week delivery time. Rooted stem cuttings from CIP were carried successfully by courier to the Philippines. The material was of potential heat-tolerant clones. The Philippines and Korea are both exploring CIP techniques in the use of stem cuttings as a rapid multiplication tool.

A Sydney University technique of sprout proliferation *in vitro* is being pursued in the Philippines and Korea. Sprouts 1.50 cm long are excised from a parent pathogen-free tuber. They then are grown in controlled conditions in intermittently shaken flasks. The plantlets produced are divided repeatedly into budded cuttings. The final generation is rooted in sand and transplanted to a screenhouse or to the field, where good quantities of seed tubers are produced from each plant.

A cooperative trial with the Department of Scientific Research, New Zealand, is being conducted in the Philippines using true (botanical) seed from both selfed and controlled pollinations. Several lines have shown a high percentage of germination plus an acceptably high proportion of high yielding plants. One line in New Zealand approached commercial quantities obtained from the normal method of planting seed tubers.

# training program

CIP's training program is mainly organized as non-degree training which takes place at the regional level. CIP recognizes that the technology generated by research can only serve a useful function when it reaches the national programs and, ultimately, through these programs the farmers of developing countries which CIP is attempting to serve. The transfer of technology implies that a receiver is capable of utilizing the technology. Unfortunately, there is often a severe shortage of trained scientists and technicians in the countries which have the greatest need fo improved technology. For this reason, even though training is not CIP's first priority, it becomes an important element in the "transfer process".

Tha main feature of CIP's regional training is that it is integrally related to CIP's regional research activities. One budget supports regional research and regional training activities in each region. Regional research and training staff are directly involved in the multiplication, evaluation and redistribution of CIP technology and germ plasm to the countries of the region where they are located. CIP's training courses are conducted in association with this process.

The second essential feature of CIP's regional training program is that it is conducted in collaboration with national potato programs. National potato program scientists always participate as instructors in CIP's regional courses. National potato programs also provide local facilities, transportation, land for demonstration plots, and contribute toward the support of regional courses.

Specialized and individual training is frequently carried out in CIP's Lima facilities in association with the headquarters' scientists. Examples of the type of training include: virus detection and identification, rapid propagation of germ plasm including meristem propagation for disease elimination, specialized training in pathology techniques, breeding techniques and utilization of the germ plasm collection, and construction and management of low-cost storage.

On a more advanced level, CIP finances training scholarships in association with local and foreign universities with the intention of providing a greater number of scientists to reinforce national research programs. There is also a system of post-doctorate posts to investigate specific research projects generally for a two-year period. The present situation regarding these scholarships is given in Table 37.

**Table 37 –** CIP TRAINING SCHOLARSHIPS APRIL 1978

| CODE | N A M E | COUNTRY | SOURCE OF FUNDS | CIP DEPARTMENT | DEGREE | UNIVERSITY | DATE COMMENCE | DATE TERMINATE (ESTIMATED) | SUPERVISING SCIENTIST | N O T E S |
|---|---|---|---|---|---|---|---|---|---|---|
| A 1 | JOSE M. LECAROS | PERU | CORE | BREEDING & GEN. | M.S. | U.N.A. | AUG. 77 | AUG. 79 | MENDOZA | COMBINING ABILITY OF ANDIGENA |
| A 2 | WALTER AMOROS | PERU | CORE | BREEDING & GEN. | M.S. | U.N.A. | NOV. 76 | JULY 78 | MENDOZA | HETEROSIS |
| A 3 | JUAN MANDUJANO | PERU | CORE | PATHOLOGY | M.S. | U.N.A. | JAN. 77 | DEC. 78 | FRENCH | SOIL SURVIVAL OF P.SOLANACEARUM |
| A 4 | VILMA BELTRAN | PERU | CORE | PATHOLOGY | M.S. | U.N.A. | MARCH 76 | DEC. 78 | FRENCH | ERWINIA SP. TUBER RESISTANCE |
| A 5 | | | CORE | NEMATOLOGY | | | | | | |
| A 6 | CARLOS EGOAVIL | PERU | CORE | PHYSIOLOGY | M.S. | U.N.A. | JAN. 76 | DEC. 79 | GLAS | DROUGHT |
| A 7 | MARIO RODRIGUEZ | PERU | CORE | PHYSIOLOGY | M.S. | U.N.A. | JAN. 77 | DEC. 78 | GLAS | SALINITY |
| A 8 | | | CORE | PATHOLOGY | | | | | | |
| A 9 | ANA MARIA MAGUINA | PERU | CORE | PHYSIOLOGY | M.S. | U.N.A. | JAN. 78 | JAN. 79 | SHAW | NUTRITION |
| A 10 | MONICA LAZARO | PERU | CORE | NEMATOLOGY | M.S. | U.N.A. | FEB. 77 | FEB. 79 | FRANCO | BIOLOG. CONTROL OF HETERODERA |
| A 11 | JORGE ABAD | PERU | CORE | PATHOLOGY | M.S. | U.N.A. | MARCH 76 | OCT. 78 | FRIBOURG | VIRUS PROBLEMS |
| A 12 | | | CORE | NEMATOLOGY | | | | | | |
| A 13 | | | CORE | PHYSIOLOGY | | | | | | |
| A 14 | COMMITTED | | CORE | RR & T | | | | | | |
| A 15 | COMMITTED | | CORE | RR & T | | | | | | |
| A 16 | | | CORE | RR & T | | | | | | |
| A 17 | | | CORE | RR & T | | | | | | |
| B 1 | MANUEL CANTO | PERU | CORE | NEMATOLOGY | PH.D. | CORNELL | JUNE 78 | JUNE 81 | BRODIE | NEMATOLOGY |
| B 2 | FRANCISCO MUROZ | ECUADOR | CORE | BREEDING & GEN. | PH.D. | CORNELL | JAN. 77 | DEC. 79 | PLAISTED | ANDIGENA POPULATIONS |
| B 3 | COMMITTED | COLOMBIA | CORE | PATHOLOGY | | | | | | |
| B 4 | LUIS VALENCIA | PERU | CORE | NEMAT./ENTOMOLOGY | PH.D. | QUEENSLAND | JUNE 78 | JUNE 81 | BLOOD | ENTOMOLOGY |
| B 5 | OSCAR HIDALGO | PERU | CORE | RR & T | PH.D. | NCSU | JAN. 78 | DEC. 80 | ECHANDI | PATHOLOGY |
| B 6 | LUIS MANRIQUE | PERU | CORE | PHYSIOLOGY | PH.D. | HAWAII | SEPT. 77 | DEC. 80 | MEYER | TECHNOLOGY TRANSFER TROPIC.SOILS |
| B 7 | CHENG SONG TAY | TAIWAN | CORE | TAXONOMY | PH.D. | BIRMIN. | APRIL 77 | APRIL 79 | OCHOA | CHEMO-TAXONOMY CULTIV. DIPLOIDS |
| B 8 | JUAN LANDEO | PERU | CORE | BREEDING & GEN. | PH.D. | WISCON. | JULY 76 | JULY 79 | HANEMANN | POTENTIAL OF ANDIGENA IN BREED. |
| B 9 | COMMITTED | SRI LANKA | CORE | RR & T | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B 10 | COMMITTED | PERU | CORE | PHYSIOLOGY | | | | | | | |
| B 11 | COMMITTED | NEPAL | CORE | RR & T | M.S. | | | | | | |
| B 12 | | | CORE | RR & T | | | | | | | |
| C 1 | TJAART GLAS | HOLLAND | CORE | PHYSIOLOGY | POST-DOC | CIP | SEPT. 77 | APRIL 79 | | | PHYSIOLOGY OF DROUGHT RESISTANCE |
| C 2 | | | CORE | RR & T | | | | | | | |
| C 3 | PETER SCHMIEDICHE | GERMANY | CORE | BREEDING & GEN. | POST-DOC | CIP | OCT. 77 | SEPT. 79 | | | BREEDING |
| C 4 | | | CORE | | | | | | | | |
| C 5 | | | CORE | | | | | | | | |
| C 6 | ROBERT WERGE | USA | RF/CORE | RR & T/SOCIAL S. | POST-DOC | CIP | OCT. 75 | DEC. 78 | | | ANTHROPOLOGY |
| C 7 | BURKHARDS SATTELMACHER | GERMNAY | CORE | PHYSIOLOGY | POST-DOC | CIP | JAN. 77 | JUNE 81 | | | HORMONE CONTROL OF TUBERIZATION |
| C 8 | CHARLES BROWN | USA | CORE | BREEDING & GEN. | POST-DOC | CIP | SEPT. 77 | AUG. 79 | | | RESISTANCE TO VIRUS DISEASES |
| D 1 | MICHAEL LAZIN | USA | CONTRACT | BREEDING & GEN. | MS & PH.D | CORNELL | APRIL 76 | MAY 79 | EWING | | HEAT & PHOTOPERIOD INTERACTION |
| D 2 | | | CONTRACT | PHYSIOLOGY | M.S. | U.N.A. | | | | | |
| D 3 | BRAULIO LA TORRE | PERU | CONTRACT | PHYSIOLOGY | M.S. | U.N.A. | OCT. 77 | DEC. 78 | FELIPE-MORALES | | CULTURAL PRACTICES & EROSION |
| D 4 | ROLANDO CABELLO | PERU | CONTRACT | PHYSIOLOGY | M.S. | U.N.A. | APRIL 77 | DEC. 78 | VILLAGARCIA | | PHOSPHATE FERTILIZATION |
| D 5 | ULISES VEGAS | PERU | CONTRACT | PHYSIOLOGY | M.S. | U.N.A. | APRIL 77 | DEC. 78 | VILLAGARCIA | | PHOSPHATE FERTILIZATION |
| D 6 | MARGARITA VILLAGARCIA | PERU | CONTRACT | PHYSIOLOGY | M.S. | U.N.A. | APRIL | DEC. 78 | VILLAGARCIA | | PHOSPHATE FERTILIZATION |
| E 1 | ALBERTO SALAS | PERU | STAFF | TAXONOMY | M.S. | U.N.A. | | | MENDOZA/OCHOA | | NON-REDUCED GAMETES |
| E 2 | SATURNINO VARGAS | PERU | STAFF | BREEDING & GEN. | M.S. | U.N.A. | APRIL 77 | | MENDOZA | | |
| F 1 | ARTURO MOREIRA | BOLIVIA | CORE | PATHOLOGY./RR & T | M.S. | U.N.A. | APRIL 76 | AUG. 78 | JONES/FRIBOURG | | BOLIVIAN VIRUSES |
| F 2 | CARLOS ALARCON | BOLIVIA | CORE | B & G/RR & T | M.S. | U.N.A. | APRIL 76 | DEC. 78 | HUAMAN/JATALA | | NACOBBUS RESISTANCE |
| F 3 | DEMETRIO UNTIVEROS | PERU | CORE | PATHOLOGY | M.S. | U.N.A. | JAN. 77 | JULY 78 | TURKENSTEEN | | THECAPHORA RESISTANCE |
| F 4 | LUIS CARTIN | C.RICA | BID-CORE | PATHOLOGY | M.S. | CHAPINGO | JAN. 77 | JULY 78 | | | |
| F 5 | JESUS CAMACHO | MEXICO | BID-CORE | PATHOLOGY | M.S. | CHAPINGO | JAN. 77 | JULY 78 | | | CHEMICAL CONTROL OF HETERODERA |

## Region I: South America

During 1977, 23 scientists and technicians from nine Latin American countries participated in Region I training activities.

The major activity included a three-month course on potato production (with emphasis on seed production) conducted in Peru. There were seven participants representing Bolivia, Colombia, Costa Rica, Ecuador, Peru and Venezuela.

The Second Latin American Coordination Meeting of potato research and production activities, in conjunction with the Asociación Latinoamericana de Papa (ALAP), was held in Puerto Varas, Chile in January 1977. Leaders and representatives from nearly all Latin American national programs and 11 CIP scientists participated.

Visiting scientists and technicians who participated in Region I training activities during 1977 came from Brazil, Bolivia, Chile, Colombia, Ecuador, Honduras, Peru and Venezuela. These scientists and technicians participated in the following training activities: meristem culture for the eradication of virus, rapid multiplication techniques, storage, plant breeding methods, disease control, the use of indicator plants and serological techniques for virus detection and identification, agronomic experiments, nematode control and seed production.

A principal feature of the 1977 training in Region I was the emphasis on subregional courses. These were conducted in Colombia, for the Northern countries (Ecuador, Bolivia, Peru and Venezuela) and for the Southern countries (Chile, Argentina, Uruguay and Brazil) in Temuco, Chile.

## Region II: Mexico, Central America and The Caribbean

A four-month potato production course was conducted in Toluca with emphasis on seed production. The course was offered in cooperation with INIA (National Research Agricultural Institute) and CIDAGEM (Mexico State Agricultural Research Center) and financed by CIP. Seven trainees from Mexico, Guatemala, El Salvador, Honduras, Nicaragua, and the Dominican Republic participated in the training course.

Two research internships were awarded to scientists from Honduras and Mexico. The scientists worked on late blight, and seed production and plant breeding, respectively. Trainees from Mexico and Honduras were recommended and accepted to participate in the Wageningen Potato Production Course.

Two scholarships for M.S. studies at Chapingo University (Mexico) were awarded in January to one scientist from Costa Rica and one from Mexico. Both scientists are specializing in plant pathology with an emphasis on potato diseases.

Three policy makers in countries from Region II visited Lima; two participated in CIP's Five Year Celebration. A scientist from Chapingo University participated in a nematology meeting in Lima, Peru.

In July, a national potato training short course was held in the main potato production area in Honduras. This 10-day course was organized by the Ministry of Agriculture of Honduras in cooperation with IICA and CIP. Twenty-five public officials and 25 potato farmers participated in the course.

## Region III: Tropical Africa

A total of 16 trainees from the region participated in a three-week regional seed production course in Nairobi in May 1977. Countries represented were: Kenya, Malagasy, Sudan, Ethiopia, Tanzania, Swaziland, Lesotho and Nigeria.

One student from the East Africa Quarantine station was trained at CIP – Lima in virology and production of disease-free vegetative material. The duration of the course was three months.

In a cooperative storage and economic study coordinated by CIP, one Kenyan student is studying at the University of Nairobi for an M.S. degree.

One student from the Tanzanian Potato Project was selected for training at the International Agriculture Center in Wageningen, the Netherlands in April 1977.

## Region IV: Middle East and North Africa

Two one-month inter-regional potato production courses were held in Tunisia (April 3-30) in French, and in Turkey (September 4-30) in English. Sixteen participants from Turkey, Tunisia, Syria, Morocco, Algeria, Rwanda and Burundi attended the Tunisian course. In Turkey, eight participants from Turkey, Syria, Jordan, Tunisia and Iran attended; GTZ, Germany, sponsored one scientist who will work on a bilateral seed project in Pakistan which CIP will support technically.

Several short courses involving eight trainees in potato production, seed multiplication and field roguing were given by national programs in Turkey, Tunisia and Syria assisted by CIP staff. In-depth production training was conducted for nine Turkish and Tunisian scientists. Three Turkish scientists went to the U. K. for graduate training, while a Sudanese scientist enrolled in Ph. D. studies at the University of Wisconsin. The Region VI Regional Scientist spent an orientation period in Izmir prior to his assignment to India.

An inter-regional workshop/seminar on potato improvement and marketing constraints was held at Izmir on October 4-14, 1977, for 23 potato specialists from seven countries in the Region.

In addition to publication in English and French of production course manuals, various training materials and slides were made available to national programs. Assistance was given in the development of potato research programs in seven countries, as well as assistance in the development of research project proposals for funding.

## Region V: Southwest Asia

The Southwest Asian program was recently initiated and involves Pakistan, Afghanistan and Iran. Ir. H. Sparenberg of IBVL, Wageningen, visited Pakistan for 16 days to advise on the storage of seed and table stock under local environmental conditions. Visits were made to the Swat and Kaghan valleys in the Northwest Frontier Province and to Baluchistan.

The Regional Representative was a participant at the Second FAO/SIDA seminar, on "Field Food Crops in the Near East and North Africa", held at Lahore in September. The coordinator of the Pakistan National Potato Program attended the inter-regional workshop/seminar held in Izmir, Turkey, during October.

Two short visits were made to Kabul, Afghanistan, in July and August for preliminary discussions with government officials.

The Regional Representative visited Tehran, Iran, July 7-12, in connection with the inter-regional course and workshop/seminar in Izmir, Turkey. A potato specialist from the extension service and one from the Horticultural Station, Shahroud, attended the September potato production course in Izmir, Turkey.

## Region VI: India, Nepal and Bangladesh

CIP's Region VI program was established in India in mid-1977. The agreement between CIP and the Government of India provides for the exchange of scientists and technology, the exchange of scientific literature, information and methodology, the offer of fellowships to scientists and technicians of the national program for short term training, as well as advanced degree and post-doctoral programs. The training program planned for 1978 will be conducted in cooperation with the Central Potato Research Institute at Simla.

Trainees from Nepal and Bangladesh participated in the Indian production course in November 1977.

## Region VII: Southeast Asia

Considerable time was spent during the latter part of 1977 in preparations for the Second Regional Potato Symposium which was held in the Philippines in February 1978. The theme chosen for the Symposium was "Pathogens and Pests of the Potato in the Tropics".

Many scientists from the Region worked or visited CIP headquarters for individual training. A scientist from the University of the Philippines at Los Baños (UPLB) spent three weeks training in bacterial wilt isolation and testing techniques under the supervision of the Pathology Department, another from the same University worked on virology identification and detection techniques.

Two scientists from Korea spent three months at Lima specializing in breeding and post-harvest technology. A pathologist from Sri Lanka studied various techniques appropriate to research on bacterial wilt of potato. She has since gone to work with our contract in Wisconsin University, USA and will eventually embark on a M. S. study.

Continuing our link with Australian institutions, a physiologist spent several weeks in Sydney University, Australia specializing in tissue culture. The physiologist will be in charge of rapid multiplication of potato germ plasm in the Philippines.

The first and second seed production courses at the Plant Research Institute, Burley, Victoria, Australia, were attended by scientists from the Philippines, Korea, Sri Lanka and Indonesia. A scientist from Sri Lanka attended the IAC Potato Production Course at Wageningen, the Netherlands.

Approximately 40 persons participated in a five-day production school held in Korea and supported by CIP scientists.

## social science unit

During 1977 the Social Science Unit (SSU) narrowed its research scope to three areas: (1) post-harvest technology and utilization; (2) potato seed production and distribution systems; and, (3) farm-level constraints to potato production. Previously initiated work on socioeconomic documentation (bibliographic research and analysis and publication of national level statistics) and contract research for the comparative study of potato production and utilization (Ecuador, Chile and Kenya) was reduced in scope. In the immediate future, the SSU will concentrate most of its resources on research in the central highlands of Peru, and on the development of training materials and methods for use in CIP courses. This implies a temporarily reduced role for the social science staff in the Center's regional programs.

In August 1977 the first Social Science Planning Conference was held at CIP. In preparation for this event, a position paper was prepared which summarizes work to date and outlines a work plan for the immediate future. The main elements of this plan are in-depth research on farm-level production constraints, post-harvest technology and utilization, and potato seed production and distribution systems. The planning conference participants endorsed the plan of work outlined in the position paper and stressed the importance of in-depth field research. The panel felt that national-level studies should not be emphasized, and recommended that, for at least two years, the SSU focus its resources on micro-level research in the Peruvian highlands. The panel also suggested that research activities of the SSU become formally integrated into CIP's nine research thrusts. With respect to the location of fieldwork, the panel supported plans for continuing and expanding research in the Mantaro Valley of Peru.

Bibliographic research on socioeconomic aspects of potatoes was initiated at CIP and is being followed up by more comprehensive searches at Cornell University and the Technical University of Berlin. The Cornell work was terminated during 1977. A bibliography is scheduled for 1978 publication by the Technical University of Berlin.

Statistical work carried out over the last year culminated in the late 1977 publication of the CIP Potato Atlas.

The national-level study of potato production and utilization in Ecuador was completed in 1977. The Kenya and Chile studies are scheduled for completion by mid-1978. All three reports will be published by the Center in 1978. No other country studies will be carried out until at least 1979.

Farm-level social science research was initiated in 1976, with an anthropological study of storage practices in Peru's central highlands. Some results of this research were reported in the 1976 Annual Report. A Center publication entitled "Potato Storage Systems in the Mantaro Valley Region of Peru" was published in early 1977. More recently, socioeconomic research on post-harvest technology in the Mantaro area was broadened to include potato processing activities.

**Post-harvest Technology: Storage**

The investigation of post-harvest technology is an integral part of CIP's Thrust VIII whose aim is to develop low-cost storage and processing technology which can be used by small farmers at the village level. While the distribution (marketing) and consumption patterns are critical aspects of post-harvest technology, investigation has so far concentrated on indigenous storage and processing techniques in the Mantaro Valley region. This is where the Huancayo experiment station is located and where CIP's technical work on storage and processing methods has been concentrated to date.

In late 1976 a study was undertaken to describe why and how potatoes are stored in the Mantaro Valley region. The study utilized two methods of investigation, including the key informant interview of individuals having a broad knowledge of potato production and distribution in the region. More than 70 farmers and officials were interviewed and numerous farm visits made to examine different types of storage techniques. During the last two weeks of study, structured interviews were held with 20 farmers to gather preliminary quantitative information on storage practices. The farmers were interviewed without a formal questionnaire because they were questioned while working in the field. The farmers' responses were recorded after the conversation had been terminated. Information gathered from this initial sample will be compared later with results gathered in a larger sample of farmers (124) as part of a study of processing techniques. The information will also be compared to the results of a comprehensive production survey of the entire Mantaro Valley region.

The most important alternatives for a farmer at harvest were found to be: (1) immediate sale or exchange; or, (2) storage for on-farm consumption, seed, animal feed or processing. All farmers who grow potatoes in the Mantaro Valley region store some part of their production, but the amount varies with the type of producer. For example, farmers with small holdings (less than two hectares in potatoes) store a larger percentage of their production than do growers with larger holdings (see Table 38). Farmers with small holdings store production principally for on-farm consumption and for seed, but also keep potatoes for animal feed and processing. Growers with larger holdings, on the other hand, primarily store potatoes for seed and only a minor amount for home consumption. Processing and animal feed are unimportant forms of post-harvest utilization for large growers.

Besides examining the functions of storage in the overall pattern of post-harvest utilization, the study also looked at the physical types of storages. Three main types were found to exist: house storages, outbuildings, and field storages. The most common place for potato storage was found to be the farmer's house (for security and convenience). Storage space in the house is multi-purpose; when the potatoes are not being stored, something else is kept in their place.

Within the house, distinctions are often made between appropriate places for seed and ware (consumer) potatoes. These distinctions are based upon the perceived characteristics of the crop. Seed potatoes need to keep their shape and handling should be minimized; therefore, these potatoes are kept on the ground floor. The potatoes are separated from direct contact with the earth by a layer of straw or other material which provides for air circulation under the pile. Eucalyptus leaves and grasses such as muña and retama, whose odors are believed to repel insects, are used extensively. Ware potatoes, on the other hand, need a dark place where sunlight entering through doors and windows does not turn the potatoes green, and therefore, the attic is a preferred location. Householders were found to prefer potatoes which had sweetened while being allowed to "spoil" and this preference also favored the use of the attic for ware potatoes.

**Table 38 — Post-harvest utilization of potato production on farms in the Mantaro Valley region (N = 20)**

| | Utilization of Potato Production (percent of total potato harvest) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stored | | Sold | | Processed | Animal Feed | Total |
| | Ware | Seed | Ware | Seed | | | |
| Small farms (less than 2 ha in potatoes) | 37 | 22 | 20 | 3 | 8 | 10 | 100% |
| Medium farms (2-10 ha in potatoes) | 3 | 10 | 70 | 11 | 4 | 2 | 100% |
| Large farms (over 10 ha in potatoes) | 6 | 14 | 40 | 40 | — | — | 100% |

Outbuildings are constructed by large-scale growers who tend to build special storage buildings, not only for potatoes, but also for tools, fertilizers, and other crops. Like house storages, outbuildings are multi-purpose, a characteristic examplified by the use of converted stables for storage. Specialized buildings for potato storage were rarely encountered. The University of Huancayo operates a potato storage facility built in the 1960's which uses wooden bins, but the design has not been copied by farmers.

Field storages, built with straw and earth either above or under the ground, are used on a limited scale almost exclusively for seed potatoes. The storages are made feasible by the fact that the normal storage period for seed — April to October — is a time in which little or no rain falls. The main disadvantages noted by farmers are the high labor input required for an initial selection of the tubers and the care needed to guard field storages against widespread theft of crops.

## Post-harvest Technology: Processing

During 1977, a six-month study of potato processing was conducted in the highland province of Concepcion in the Mantaro Valley region. Fieldwork was carried out by a Dutch student of rural sociology and several Peruvian students. The group spent an initial period gathering descriptions of all food processing technology in the area, as well as information on other post-harvest practices such as sale, storage and animal feed. During the second phase of the study, a survey using a formal questionnaire was carried out with 120 farmers in the province. For purposes of the study, the province was divided into three major production zones on the basis of altitude and crop complex. The lowest zone, from 3,200 - 3,400 m, is dominated by potato and corn which is often irrigation grown. The two higher zones (3,400 - 3,600 m and over 3,600 m) are dedicated to dry-land production of potatoes, barley and natural pasture. In the highest zone, bitter potatoes and olluco, another Andean tuber, are important crops.

Among the preliminary results of the study were:

1. Food processing was found to be a common household activity carried out with home consumption as the main purpose. Over 90 percent of the households in which interviews were conducted, processed corn and barley products and nearly 40 percent processed potatoes. Women provided most of the processing labor. Of the 52 households who reported processing potatoes, only five sold part of this production. Several privately-owned mills provided the only example of village level processing.

2. Food processing utilizes simple and inexpensive implements commonly found in and around the house. For example, papa seca, a dehydrated product made by cooking and sundrying potatoes, needs only firewood, a cooking pot, and a sack or sheet of tin on which the cooked and peeled potatoes are placed in the sun to dry. Food processing techniques make abundant use of natural materials and phenomenon, not only sunlight, but also frost, streams and natural grasses for straw.

3. The technology involved in processing potato products is highly labor intensive (see Table 39). Farmers responded that the high labor input, coupled with generally low levels of production, are the main factors limiting potato processing. Less than five percent of total production goes into processed products.

4. The principle motivation of potato processing appears to be the desire to consume potatoes which cannot be eaten fresh. This category includes all the frost-resistant bitter varieties (*Solanum jucepczukii* and *Solanum curtilobum*) which must be processed before eaten because of their high glycoalkaloid content. When other varieties are used for processing, the tubers are usually small, damaged or diseased. An additional factor which limits the conversion of this type of material into processed products is their alternative use as animal feed.

5. The two principle potato products, chuño and papa seca, appear to have very different uses in the Peruvian national and local diet. Chuño is primarily made from bitter potatoes by exposing the tubers to frost, pressing to squeeze out moisture, soaking in running water, and drying in the sun. Chuño is made in the higher, marginal production areas where bitter potatoes are grown, and, considered to be primarily peasant food; it is not widely consumed by the urban population. Papa seca, on the other hand, is associated with coastal and urban dietary patterns and is marketed in Lima and other large cities.

**Table 39 – Estimated labor input for processing 23 kgs of potatoes into papa seca and chuño**

| Papa Seca | | Chuño | |
|---|---|---|---|
| Process | Hours | Process | Hours |
| 1) select | 0.5 | 1) select and grade | 0.5 |
| 2) boil | 1.0 | 2) spread out to expose to frost | 1.0 |
| 3) peel | 9.0 | 3) check degree of freezing | 2.0 |
| 4) break into small pieces | 0.5 | 4) gather and stamp | 1.0 |
| 5) place in sun and cover at night (4-8 days) | 2.0 - 4.0 | 5) construct pool | 5.0 - 8.0 |
| | 13.0 - 15.0 | 6) place in pool, cover with straw and rocks | 2.0 |
| | | 7) remove from pool | 1.0 |
| | | 8) spread to dry on straw (5-10 days) | 1.0 |
| | | 9) gather when dry | 1.0 |
| | | | 14.5 - 17.5 |
| 23 kgs = 5 kgs papa seca | | 23 kgs = 8 kgs chuño | |

## Potato Seed Production and Distribution Systems

The socieconomic research on seed production and distribution has been endorsed both by the TAC Quinquennial Mission as well as the recently held Social Science Planning Conference (August 1977). It has been performed within the scope of Thrust IX: Seed technology for developing countries.

The research was focused on building an information base on seed systems prevailing in some selected developing countries (Colombia, Chile, Ecuador, Peru). The starting point was the hypothesis that the new seed technology, regardless of its origin, has to be delivered to farmers through a national seed system, which itself may become a major constraint for technology transfer. The research was, then, oriented to fulfill three specific objectives: a) to describe and analyze the organization and rationality of the production and distribution seed system; b) to identify tha main factors affecting its viability; and, c) to describe how they transfer the new seed technology.

On the basis of the analysis of the seed systems in Colombia, Chile, Ecuador and other countries, an attempt was made to conceptualize the institutional organization needed to produce and deliver certified seed in a developing country. An institutional model for basic seed with clonal selection of varieties and with a public-private multiplication and distribution system of certified seed was developed. One notable finding was that developing countries, when initiating certified seed programs, very often forgot or did not take into account the conditions or assumptions that should be satisfied for the proper operation of the model.

Four major economic and institutional barriers affecting the viability of the certified seed system in developing countries were identified and analyzed: a) the lack of capacity of the National Programs to produce a sufficient and uninterrupted flow of basic seed; b) adequate organization and know-how of potato programs; c) the rapid deterioration of sanitary levels of the certified seed on its way toward the final user; and, d) the lack of demand for certified seed at prices covering production cost and normal profit.

Due to the general lack of information on seed production and distribution systems in developing countries, a socioeconomic bibliography on seed is being prepared. With a Ford Foundation grant, a research project on seed production systems has been carried out since January 1978 in Colombia and Ecuador.

Micro-level research has been performed in Ecuador, Peru, Chile and Kenya. A methodology based on farm-level surveys has been applied in each country. The main focus of this research has been the use of seed and the effects of improved seed on farm output and incomes. Among others, the following hypotheses are being tested:

1. Improved varieties have lower yields than traditional ones without the use of complementary inputs.

2. There is a strong demand for high quality seed, which has not been satisfied by the official seed production services.

3. Improved varieties are produced for market; traditional varieties are produced for self consumption.

4. When production can be sold both as seed and as ware potato, price relationship between ware potato and seed is critical in deciding what proportion of the farmer's total output will be kept as seed.

5. Under conditions of low input application, high quality seed impact is not expressed.

An anthropological research study on potato folk taxonomies and seed networks in Peru was initiated this year by an American anthropologist. The overall objective of this research is to analyze the cultural framework and economic mechanisms whereby new potato varieties are identified, adopted, and distributed among Peruvian peasants. This objective may be broken down into two specific areas of research: the study of folk taxonomies associated with potato and the study of seed distribution networks.

Three major locations have been selected to conduct this research: a) Mantaro Valley (Chicche and Pasos); b) Cuzco region (Chinchero, Urubamba, Pampallacta and Chuquibambilla); and, c) Puno region (Cuyo-Cuyo). The methodology being applied includes questionnaires taken to farmers, marketing surveys and taxonomic techniques.

**Farm-level Constraints to Potato Production**

In 1977 a series of studies on potato production, distribution and utilization was initiated in the Mantaro River basin. The main objectives of this research are to provide data for the SSU's three areas of in-depth research and to provide a "laboratory" for field testing and training activities.

From March until September 1977, anthropological research was carried out to define the major agricultural land-use zones in which potatoes are grown. These zones were mapped and described in terms of their natural/ecological conditions, market orientation, production and post-harvest systems, land tenure and size of farm unit.

This research provided the framework for a single-interview survey of 250 maize and potato growers in the region, carried out jointly by CIMMYT and CIP. By the end of 1977 data from this survey had been coded for computer processing and analysis.

Beginning in late 1977, a subset of approximately 25 producers from the previously surveyed larger sample is being followed through an entire production cycle, using a multiple-interview survey technique. Producers are visited by interviewers each week, and detailed accounts are kept on their economic activities. This information is being used to analyze socioeconomic aspects of potato production technology in the region. Over the same 1977/78 production cycle, data on soil nutrients, plant growth, diseases and pests, cultural practices, and other agronomic variables are being recorded for a large sample of producers (50 - 75) and utilized in an analysis of factors limiting yields. In the 1978 planting season, on-farm experiments will be initiated in the Mantaro region to test agronomic and economic aspects of improved practices under field conditions.

In Kenya, an economic analysis was made of potato production in various areas. Primary data were obtained through a farm survey in six producing areas. In the farm survey, major emphasis was placed on husbandry techniques, inputs, yields, costs of production, profits and market outlets. Between November 1976 and April 1977, a total of 460 farmers were contacted, out of which 441 grew potatoes in the six production areas.

The survey data were analyzed preliminarily and the results compiled in brief reports, which were distributed to institutions and individuals involved in the potato sector. A more detailed computer analysis of the data is being prepared. Some preliminary results of the producer survey are presented in the following tables.

**Table 40 – Pattern of production and utilization of potatoes in six potato producing areas in Kenya**

| Producer area | Farm size | Size of potato plot | Utilization of the crop | | |
|---|---|---|---|---|---|
| | | | Sale of ware | Consumption on farm | Own seed |
| | ha | ha | percent | percent | percent |
| 1. Molo | 3.5 | 0.4 | 39 | 36 | 25 |
| 2. 01 Kalou | 12.3 | 0.3 | 32 | 41 | 25 |
| 3. Kinangop | 8.0 | 0.3 | 27 | 48 | 25 |
| 4. Kiambu | 1.7 | 0.2 | 14 | 54 | 32 |
| 5. Nyeri/Muranga | 2.1 | 0.2 | 18 | 54 | 27 |
| 6. Meru | 5.9 | 1.3 | 61 | 19 | 21 |

**Table 41 – Inputs and yields in six potato producing areas in Kenya**

| Producer area | Frequency of use | | | Chemical | Seed | Yield |
|---|---|---|---|---|---|---|
| | Mechanical land preparation percent | Mineral fertilizer percent | Chemical disease control percent | for blight control kg/ha | rate tons/ha | tons/ha |
| 1. Molo | 44 | 31 | 4 | 0.3 | 1.3 | 4.5 |
| 2. 01 Kalou | 63 | 71 | 10 | 0.4 | 1.4 | 5.2 |
| 3. Kinangop | 61 | 54 | 5 | 0.5 | 1.3 | 5.2 |
| 4. Kiambu | 17 | 65 | 35 | 3.5 | 1.6 | 4.8 |
| 5. Nyeri/Muranga | 0 | 79 | 79 | 3.0 | 1.4 | 5.1 |
| 6. Meru | 89 | 42 | 100 | 9.0 | 1.9 | 9.4 |

**Table 42 – Economics of potato production in six producing areas in Kenya**

| Producer area | Farm gate price Kshs/ton * | Output Kshs/ha | Costs of production Kshs/ha | Returns Kshs/ha |
|---|---|---|---|---|
| 1. Molo | 475/ – | 2160/ – | 1851/ – | 309 |
| 2. 01 Kalou | 400/ – | 2061/ – | 2260/ – | - 199 |
| 3. Kinangop | 288/ – | 1515/ – | 1701/ – | - 186 |
| 4. Kiambu | 700/ – | 3330/ – | 3223/ – | 107 |
| 5. Nyeri/Muranga | 788/ – | 4054/ – | 2607/ – | 144 |
| 6. Meru | 475/ – | 4218/ – | 3219/ – | 999 |

* 1 Ksh = 0.123 US $

From the farm survey several tentative conclusions can be drawn on the production pattern in various areas.

1. In Kenya, potatoes are produced on a small scale basis; average plot size is less than 0.5 ha.
2. Yields per ha are generally low.
3. Production costs are high and returns to producers are marginal.
4. Average farm gate prices differ significantly between growing areas.
5. Production technology differs significantly between areas.

Three major types of potato producing farms have been identified:

**Type I** (Producer area 4 and 5) : Small farm size, fair technology level (high frequency of chemical disease control, low application rates) low yields, high farm gate prices, fair profits and low share of marketed crop.

**Type II** (Producer area 6) : Medium sized farms, comparatively high technology level (high frequency and rate of application of chemical disease control) fairly high yields, fair prices, fair profits and high marketed share.

**Type III** (Producer area 1, 2, 3) : Medium to large sized farms, low technology level, low yields, fairly low farm gate prices, low profits and medium marketed share.

## communications

Center Support Communications is comprised of several sections and facilities.

An editorial section consists of writing and editing Center publication. Typing facilities include two IBM memory typewriters and a composer.

The photographic facilities consist of a studio, darkrooms and a projection room which can also be used for seminars. Art work is produced in addition to layout for publications and the production of offset plates.

The printing shop has an offset press and auxiliary equipment. This section also provides routine mimeograph and photocopying services.

During 1977 the Communications section acquired new personnel and reorganized part of its work activities. One scientist was transferred to the department to work jointly in communications and training activities, an English editor/writer was hired, in addition to an audiovisual technician.

An editorial committee and a training committee were organized. The editorial committee supervises the release of all scientific and general CIP publications. Located within Regional Research and Training, the training committee contains two communication staff members and several scientists who are working to coordinate the production of training aids to facilitate the transfer of CIP technology.

Staff continued to produce art, audio-visual, photographic and printed material, including work for the Annual Report, CIP Circular, planning conference reports and other scientific reports. For the first time the offset plates have been prepared in the section.

The audio-visual and photography section have nearly finished the reconstruction of the darkroom where black and white photography is being carried out. A color slide collection has been organized for use by CIP staff, and all existing black and white photographs have been classified. Several slide sets were updated, including Potato Diseases, Greenhouse, Stem Cuttings and Storage.

At year end the CIP Circular, a monthly scientific publication was recommenced on a regular basis. The Circular, which contains articles on Center research, is distributed to about 2,000 people (mostly potato scientists) in the developing and developed world. A full-color field reference handbook. "The Potato: Major Diseases and Nematodes," was also published. All publications are published in English and Spanish.

The department continues to host slide-shows, seminars and workshops in its mini-auditorium which has projection facilities and a seating capacity for 20 people. A full-sized auditorium with seating for approximately 80 people was opened in mid-year in the new wing of the main building. Larger seminars and planning conferences are held there.

**Godofredo Lagos, pressman, makes adjustments on the offset press used by CIP Communications in preparing printed materials.**

## LIBRARY

The Library moved into its new facilities as scheduled in mid-1977 greatly relieving the previously occupied cramped work area. Conveniently situated at the junction of the new training and research wings, it is also directly accessible to the main entrance. The book stacks and twelve carrels occupy two floors. Below is a basement where future audio-visual material will be located. The total area of approximately 248 $m^2$ provides ample space for continued expansion of the Library collection. The illumination and general airiness of the new Library has encouraged a marked increase in its use.

The Library collection of selected scientific reference texts has been gradually increased to a total of approximately 1,800 volumes. The reprint collection continued to grow during the year due to the demand by CIP scientists for current and specialized information. At present the Library staff has processed over 2,000 reprints. Journal subscriptions now total 87; 27 of which have been donated for a two-year period by the British Council. Through the services of the Commonwealth Agricultural Bureaux, which scans over 8,000 journals, indexed "Potato Abstracts" have been made available to provide a flow of information for CIP scientists at Lima and in regional headquarters.

The Library provides a communication link to a number of information sources. Through routine distribution of textbook catalogues, CIP staff is informed of new texts. Collaboration with the libraries of the nearby National Agricultural University and the Ministry of Food and Agriculture continues to provide exchange and inter-library loan services to augment CIP's reference sources. Additional exchange services are provided through agreement with other Centers of the Consultative Group network.

As a member of the "Asociación de Bibliotecarios y Documentalistas Agrícolas del Perú" (ABYDAP), the Library was represented at the First Course on Methodology of the Information Systems AGRINTER-AGRIS and at the Third Round Table of ABYDAP in November, 1977.

In early 1977 the Library staff was increased by the hiring of an assistant librarian. The head librarian entered the University of Sheffield, England, on a scholarship granted by the British Council. During her one-year study leave toward the M. S. degree in Information Science, two employees were hired on a temporary basis.

Toward year end the extensive socioeconomics reference collection was transferred to the Library for integration into the Centers reference collection.

## Visitors and Language Instruction

As CIP becomes better known there has been a marked increase in the number of visitors. During 1977 414 professionals, officials and trainees from 42 countries visited the Center, a three-fold increase over 1976. In addition many professional and interested persons from Peru visited CIP.

As in previous years, language instruction was offered to staff and wives. Mr. Jorge Palacios taught Spanish to 21 staff members and 11 wives through scheduled morning lessons, normally of one-half hour duration, two or three days a week. Earlier in the year three Spanish-speaking technicians were instructed in English.

# publications by CIP scientists


1. **Abad, J.**, and **C. E. Fribourg.** 1977. Preliminary characterization of a virus isolated from potato accessions from Peru and Bolivia. Fitopatología 13. (In press).

2. **Alarcón, C.**, and **P. Jatala.** 1977. Effect of temperature on the resistance of *Solanum andigena* to *Nacobbus aberrans*. Nematropica. 7:2-3.

3. **Armstrong, Judith M.**, **P. Jatala**, and **H. J. Jensen.** 1976. Bibliography of nematode interactions with other organisms in plant disease complex. Western Regional Research Project. W-56. 1963-1973. Oregon State Agricultural Experiment Station. Bull. 623. Corvallis, Oregon.

4. **Canto-Sáenz, M.**, and **M. Mayer de Scurrah.** 1977. Races of the potato cyst nematode in the Andean region and a new system of classification. Nematologica. 23:340-349.

5. **Canto-Sáenz, M.**, and **M. Mayer de Scurrah.** 1977. Reproduction of eight potato cyst nematode populations in four Peruvian locations. Nematropica. 7:5.

6. **Canto-Sáenz, M.** 1977. Effect of systemic insecticides and fungicides on the potato cyst nematode. Fifth meeting of the Peruvian Society of Phytopathologists. Ayacucho, Peru. (In press).

7. **De la Puente, F.**, **I. Herrera**, **V. Vásquez**, and **E. French.** 1977. Molinera, variedad de papa resistente a la marchitez bacteriana y a la rancha. Ministerio de Alimentación, DGI, Inf. Especial 57 Lima, Peru. P.5.

8. **Estrada, R. N.** 1977. Breeding frost-resistant potatoes for the tropical highlands. In. Plant cold hardiness. University of Minnesota. (In press).

9. **Evans, K.**, and **J. Franco.** 1977. Morphological variation in some populations of potato cyst nematodes from Europe and South America. Nematologica. 23:417-430.

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13. **French, E. R.,** and **C. Martin.** 1977. Biotipos y razas de *Pseudomonas solanacearum* de la papa en las Américas. Fitopatología 12 (2): (Compendio).

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15. **Fribourg, C. E.** 1977. Andean potato calico strain of tobacco ringspot virus. Phytopath. 67:174-178.

16. **Fribourg, C. E.** 1977. Symptomatology, host range, physical properties and serological reactions of Peru tomato virus. Fitopatología 13. (In press).

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18. **Fribourg, C. E., R. A. C. Jones,** and **R. Koenig.** 1977. Andean potato mottle virus, a new member of the cowpea mosaic virus group. Phytopath. 67:969-974.

19. **Herrera, M., Isaías V. Vásquez, F. de la Puente,** and **E. French.** 1977. Caxamarca (Chaucha mejorada); nueva variedad de papa resistente a la marchitez bacteriana y a la rancha. Min. de Alimentación, Dir. Gen. Invest. Informe Especial Nº 49. Lima, Perú.

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# staff

on December 31, 1977, including Special Project Personnel

## BREEDING AND GENETICS

| | |
|---|---|
| Humberto Mendoza, Ph. D. | Head of Department |
| Nelson Estrada, Ph. D. | Breeder |
| Zósimo Huamán, Ph. D. | Geneticist |
| Charles Brown, Ph. D. | Geneticist (Post-doctorate) |
| Peter Schmiediche, Ph. D. | Geneticist (Post-doctorate) |
| Juan Landeo, M. S. | Geneticist (on leave) |
| Fernando Rey, Ing. Agr. | Breeder |

## NEMATOLOGY AND ENTOMOLOGY

| | |
|---|---|
| Parviz Jatala, Ph. D. | Head of Department |
| María de Scurrah, Ph. D. | Nematologist |
| Javier Franco, Ph. D. | Nematologist |
| Manuel Canto, M. S. | Visiting Nematologist |
| William Brodie, Ph. D. | Visiting Scientist |
| Luis Valencia, Ing. Agr. | Entomologist |
| Richard Gibson, Ph. D. | Visiting Entomologist |

## PATHOLOGY

| | |
|---|---|
| Edward R. French, Ph. D. | Head of Department |
| Lodewijk Turkensteen, Ph. D. | Mycologist |
| Carlos Martin, Ph. D. | Pathologist |
| Roger Jones, Ph. D. | Virologist |
| A.M.H. de Lekeu, Ph. D. | Virologist |
| Luis Salazar, Ph. D. | Virologist |
| César Fribourg, M. S. | Visiting Scientist |

## PHYSIOLOGY

| | |
|---|---|
| Roy Shaw, B. S. | Head of Department |
| Raymond Meyer, Ph. D. | Agronomist |
| Burkhard Sattelmacher, Ph. D. | Physiologist (Post-doctorate) |
| Primo Accatino, Ph. D. | Production Specialist |
| William Roca, Ph. D. | Physiologist |
| Tjaart Glas, Ph. D. | Physiologist |
| A. Krauss, Ph. D. | Physiologist (Germany-Berlin) |

## TAXONOMY

| | |
|---|---|
| Carlos Ochoa, M. S. | Head of Department |
| Alberto Salas, Ing. Agr. | Taxonomist |
| Chong Seng Tay, B. S. | Taxonomist (Graduate student) |

## REGIONAL RESEARCH AND TRAINING PROGRAM

### Headquarters - Lima, Peru

| | |
|---|---|
| Richard T. Wurster, Ph. D. | Director |
| Kenneth J. Brown, Ph. D. | Coordinator |
| John S. Niederhauser, Ph. D. | Senior Consultant |
| James E. Bryan, M. S. | Senior Seed Prod. Spec. |

### Social Science Unit - Lima, Peru

| | |
|---|---|
| Douglas Horton, Ph. D. | Head of Unit |
| Anibal Monares, M. S. | Economist |
| Robert Werge, Ph. D. | Anthropologist |
| Luis Quintanilla, M. S. | Socioeconomics Assistant |

### Region I - South America

| | |
|---|---|
| Oscar Malamud, Ph. D. | Regional Representative (Peru) |

**Region II – Central America, Mexico and the Caribbean**

| | |
|---|---|
| Oscar Hidalgo, M. S. | Regional Representative (Mexico) |
| Michael Jackson, Ph. D. | Research Scientist (Costa Rica) |

**Region III – Tropical Africa**

| | |
|---|---|
| Sylvester Nganga, Ph. D. | Regional Representative (Kenya) |
| Siert Wiersema, Ir. | Assoc. Research Scientist (Kenya) |

**Region IV – Middle East and North Africa**

| | |
|---|---|
| Patricio Malagamba, Ph. D. | Regional Representative (Turkey) |
| Roger Kortbaoui, Ph. D. | Research Scientist (Tunisia) |
| Brian Honess, D. T. A. | Seed Production Specialist (Turkey) |
| Willem Schrage, Ir. | Associate Research Scientist (Turkey) |

**Region V – Southwest Asia**

| | |
|---|---|
| Garry Robertson, M. A. | Regional Representative (Pakistan) |
| Romke Wustman, Ir. | Associate Research Scientist (Pakistan) |

**Region VI – India, Nepal and Bangladesh**

| | |
|---|---|
| Paul Egger, Ir. | Research Scientist (Nepal) |

**Region VII – Southeast Asia**

| | |
|---|---|
| Lindsay Harmsworth, B. S. | Regional Representative (Philippines) |

## COMMUNICATIONS

| | |
|---|---|
| Kenneth J. Brown, Ph. D | Acting Head of Department |
| Rainer Zachmann, Ph. D. | Communications Officer |
| Ayn Strattner | Editor/writer |
| María Mazzi | Audio-visual Assistant |
| Carmen de Podestá, Ba. Sc. | Librarian (on leave) |
| Martha Crosby | Librarian |
| Jorge Palacios, Dip. | Language Teacher |
| Elsa Franco | Publications |

## SUPPORT DEPARTMENT

| | |
|---|---|
| Orville T. Page, Ph. D. | Head of Department |
| Marco Soto, Ph. D. | Superintendent, Huancayo Facility |
| César Vittorelli, Ing. Agr. | Field Supervisor, Huancayo |
| Hebert Torres, M. S. | Greenhouse Supervisor, Huancayo |
| Lauro Gómez | Field & Greenhouse Supervisor, Lima |
| Nelson Melénoez, Tech. Dip. | Seed Technician |

## ADMINISTRATION

| | |
|---|---|
| Richard L. Sawyer, Ph. D. | Director General |
| Roger Rowe, Ph. D. | Deputy Director General |
| Orville T. Page, Ph. D. | Director of Research |
| William Hamann, B. S. | Assistant to the Director General |
| Carlos Bohl, Ing. Agr. | Executive Officer |
| Germán Rossani, M. D. | Medical Officer |
| Luis Palacios, Ing. Agr. | Assistant to the Executive Officer |
| Fernando Canalle, Ing. | Engineering Officer |
| Rafael García | Administrative Assistant |

| | |
|---|---|
| Oscar Gil, C.P.A. | Controller |
| Ricardo Avila, C.P.A. | General Accountant |
| Pedro Arriola, C.P.A. | Accountant |
| Blanca de Joo, C.P.A. | Accountant |
| Guillermo Romero | Accountant |
| Luis Núñez | Cashier |
| Alfredo González | Accountant Assistant |
| Estanislao Pérez | Accountant Assistant |
| Jaime Rozas | Pilot |
| Clelia Toso | Guest House and Cafeteria Administrator |

## TECHNICIANS

| | |
|---|---|
| Juan Aguilar, Ing. Agr. | Breeding and Genetics |
| Saturnino Vargas, Ing. Agr. | Breeding and Genetics |
| Luisa Arens, B. Sc. | Nematology |
| Lis de Ocampo, Ing. Agr. | Pathology |
| Liliam Gutarra de Lindo, Ing. Agr. | Pathology |
| Ursula Nydegger, Tech. Dip. | Pathology |
| Ilse de Balbo, Tech. Dip. | Pathology |
| Carlos Chuquillanqui, B. Sc. | Pathology |
| Renate Kaltenbach | Nematology |
| Sila Llerena, D. S. | Nematology |
| Ernesto Velit, Biol. | Pathology |
| Hans Pinedo, Ing. Agr. | Pathology |
| Nelson Espinoza, D. F. | Physiology |
| Nilda Beltrán, B. S. | Physiology |
| Soledad de Rodríguez | Pathology |
| Amparo de Siveroni, Q. F. | Physiology |
| Nelly de Fong, Biol. | Physiology |
| Norma González, Q. F. | Physiology |
| Rosa Méndez, Ing. Agr. | Physiology |
| Josefina de Nakashima, Biol. | Physiology |
| Donald Berrios, Ing. Agr. | Physiology |
| Rosario de Roca | Physiology |
| Matilde Orillo, Biol. | Taxonomy |
| Martha Carrillo | Regional Research (Mexico) |
| Cecilia Moreno, Ing. Zoo. | Socioeconomics |
| Hugo Fano | Socioeconomics |
| María Isabel Benavides | Socioeconomics |

COLERIDGE Y ASOCIADOS

THE INTERNATIONAL POTATO CENTER - CIP

FINANCIAL STATEMENTS AS OF DECEMBER 31, 1977

I N D E X


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Special projects funds provided and cost, Exhibit 4

**COLERIDGE Y ASOCIADOS**
REPRESENTANTES DE
ARTHUR ANDERSEN & Co.
LIMA - PERU

To the Board of Trustees of
The International Potato Center - CIP

We have examined the balance sheet of THE INTERNATIONAL POTATO CENTER - CIP (a nonprofit organization established in Perú) as of December 31, 1977, and the related statement of sources and application of funds for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying financial statements present fairly the financial position of The International Potato Center as of December 31, 1977, and the source and application of its funds for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Our examination has been made primarily for the purpose of forming the opinion stated in the preceding paragraph. The data contained in Exhibits 1 to 4 inclusive, of this report, although not considered necessary for a fair presentation of financial position and source and application of funds, are presented as supplementary information and have been subjected to the audit procedures applied in the examination of the basic financial statements. In our opinion, these data are fairly stated in all material respects in relation to the basic financial statements, taken as a whole.

Coleridge y Asociados
Representantes de
Arthur Andersen & Co

Countersigned by:

Luis Coleridge

Luis Coleridge A.
C.P.C. Matrícula No. 1234

Lima, Perú,
April 14, 1978.

# THE INTERNATIONAL POTATO CENTER - CIP

## BALANCE SHEET

(Stated in US dollars)

### ASSETS

| | As of December 31 1977 | 1976 |
|---|---|---|
| **CURRENT ASSETS:** | | |
| Cash on hand in banks | 658,419 | 282,907 |
| Accounts receivable - | | |
| Donors | 387,696 | 584,962 |
| Advances - | | |
| Principal and support staff | 66,792 | 44,304 |
| International agriculture centers and other organizations | 35,906 | 39,259 |
| Other | 93,538 | 165,570 |
| | 583,932 | 834,095 |
| Inventories | 173,491 | 133,120 |
| Prepaid expenses and other assets | 22,627 | 17,057 |
| Total current assets | 1,438,469 | 1,267,179 |
| **FIXED ASSETS:** | | |
| Buildings and construction in progress | 1,359,842 | 902,692 |
| Research equipment | 497,555 | 357,391 |
| Vehicles and aircraft | 503,938 | 345,533 |
| Furniture, fixture and office equipment | 276,912 | 96,266 |
| Operating equipment | 80,646 | 50,263 |
| Installation and Site Development | 558,582 | 203,509 |
| Other | 65,714 | 72,248 |
| | 3,343,189 | 2,027,902 |
| | 4,781,658 | 3,295,081 |

### LIABILITIES, CAPITAL GRANTS AND UNEXPENDED FUNDS

| | As of December 31 1977 | 1976 |
|---|---|---|
| **CURRENT LIABILITIES:** | | |
| Bank overdrafts | 1,389 | 213,673 |
| Accounts payable | 423,902 | 147,402 |
| Payable to donors | 66,000 | - |
| Other | 39,389 | 24,531 |
| Total current liabilities | 530,680 | 385,606 |
| **GRANTS RECEIVED IN ADVANCE** | 41,675 | 314,488 |
| **RESERVE FOR SEVERANCE INDEMNITIES** (net of advances of 3,374 in 1977 and 488 in 1976) | 63,509 | 71,303 |
| **CAPITAL GRANTS AND UNEXPENDED FUNDS:** | | |
| Capital grants - | | |
| Fully expended in fixed assets | 3,343,189 | 2,027,902 |
| Working funds | 362,000 | 340,000 |
| | 3,705,189 | 2,367,902 |
| Unexpended funds - | | |
| Capital grants (expended in excess) | 5,312 | (137,440) |
| Core | 220,485 | 54,771 |
| Special project | 214,808 | 322,158 |
| Earthquake repairs (expended in excess) | - | (83,707) |
| | 440,605 | 155,782 |
| | 4,145,794 | 2,523,684 |
| | 4,781,658 | 3,295,081 |

The accompanying notes to financial statements are an integral part of this statement.

WHITEHEAD & WHITEHEAD

COLEBRIDGE Y ASOCIADOS

## THE INTERNATIONAL POTATO CENTER - CIP

## STATEMENT OF SOURCE AND APPLICATION OF FUNDS

(Stated in U.S. dollars)

| | For the years ended December 31, 1977 | 1976 |
|---|---|---|
| **SOURCE OF FUNDS:** | | |
| Operating grants - | | |
| Unrestricted | 2,265,291 | 1,584,768 |
| Restricted, net of 66,000 payable to donors, in 1977 | 2,124,067 | 1,567,411 |
| | 4,389,358 | 3,152,179 |
| Special projects grants | 468,417 | 935,716 |
| Capital grants | 1,168,405 | 731,250 |
| Working funds | 22,000 | 155,000 |
| Other | 279,062 | 163,387 |
| | 6,327,242 | 5,137,532 |
| **APPLICATION OF FUNDS:** | | |
| Operating costs - | | |
| Core program | | |
| Potato research program | 1,241,466 | 954,111 |
| Research support | 292,017 | 270,389 |
| Regional research and training | 1,341,638 | 1,111,281 |
| Library, documentation and information service | 198,151 | 138,637 |
| General administration | 451,375 | 392,409 |
| General operating costs | 683,477 | 320,574 |
| Quinquennial review and five year celebration | 98,903 | - |
| | 4,307,027 | 3,187,401 |
| Special projects | 330,922 | 616,714 |
| | 4,637,949 | 3,804,115 |
| Capital | | |
| Additions to fixed assets | 1,226,688 | 897,595 |
| Working funds | 22,000 | 162,069 |
| Earthquake repair funds | - | 117,971 |
| | 1,248,688 | 1,177,635 |
| | 5,886,637 | 4,981,750 |
| **UNEXPENDED FUNDS** | 440,605 | 155,782 |

The accompanying notes to financial statements are an integral part of this statement.

THE INTERNATIONAL POTATO CENTER - CIP

NOTES TO FINANCIAL STATEMENTS

AS OF DECEMBER 31, 1977 AND 1976

1. SUMMARY OF SIGNIFICANT ACCOUNTING PRINCIPLES AND PRACTICES

a. The transactions are principally made in U.S. dollars and the accounts are maintained in such currency, on an accrual basis except for interest earned, that is accounted for on a cash basis. Assets, liabilities, source and application of funds arising from transactions in other currencies, are translated into U.S. dollars by use of the exchange rate in effect at the transactions date. At the balance sheet date, balances representing cash and amounts owed by or to CIP that are denominated in currencies other than the U.S. dollar are adjusted to reflect the current rate. Exchange gain and losses are included in determining the source and application of funds for the period in which the exchange rates fluctuate.

b. Inventories are reported at estimated prices, which approximate the cost determined on a first-in, first-out basis.

c. Fixed assets are recorded at cost. No depreciation is accounted for. Retirements are charged to the fully expended in fixed assets capital account. Maintenance and repairs are reported as application of funds as incurred.

d. Operating grants restricted to research, special projects, and capital and unrestricted grants are reported as source of funds in the period in which the donor's commitment is made. In accordance with the Consultative Group on International Agriculture Research instructions, the unexpended balances for core operations at year-end are carried forward to the following period, except when prior arrangements to reimburse the amounts unexpended exist; in such case the unexpended funds are reported as liabilities.

Capital grants and special project grants unexpended at year-end are carried forward to the following period. A

COLERIDGE Y ASOCIADOS

part of the operating grants is used as working funds, according to the Consultative Group instructions.

## 2. AGREEMENT BETWEEN THE GOVERNMENT OF PERU AND NORTH CAROLINA STATE UNIVERSITY

The CIP was constituted on June 13, 1972, in accordance with an Agreement for Scientific Cooperation between the Government of Perú and the North Carolina State University signed on January 20, 1971. A summary of the significant provisions of the agreement follows:

a. The objective is to establish through common or cooperative efforts a nonprofit organization of a scientific nature, dedicated to research and improvement of potatoes and tuberous roots and also to train people.

b. The CIP is a tax exempt entity established in Peru. Exemption includes income tax.

c. Non-Peruvian scientists working for the CIP are also tax exempt.

d. The agreement will be in effect for twenty years beginning on January 20, 1971. This period may be extended.

e. If for any reason the existence of the CIP is terminated, the land, buildings, equipment, vehicles and other assets of the CIP are to be transferred to the Peruvian government at no cost.

f. The CIP is authorized to maintain and utilize checking accounts in foreign currencies for all operations, subject to the provisions of the law in effect for international organizations.

## 3. COMPARATIVE FINANCIAL STATEMENTS

The balance sheet as of December 31, 1976 and the statement of sources and application of funds for the year then ended, which are presented for comparative purposes, were examined and reported on by public accountants other than Coleridge y Asociados representantes de Arthur Andersen & Co.

COLERIDGE Y ASOCIADOS

COLERIDGE & ASSOCIATES

# SUPPLEMENTARY INFORMATION

EXHIBIT 1

## THE INTERNATIONAL POTATO CENTER - CIP

## ACCOUNTS RECEIVABLE FROM DONORS

## AS OF DECEMBER 31, 1977

(Stated in U.S. dollars)

| | |
|---|---|
| Swiss Development Cooperation, Switzerland | 37,500 |
| Overseas Development Ministry, United Kingdom | 67,856 |
| Federal Germany Government | 40,570 |
| Interamerican Development Bank | 152,564 |
| Belgium Government | 89,206 |
| | 387,696 |

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EXHIBIT 2

THE INTERNATIONAL POTATO CENTER - CIP

FIXED ASSETS

FOR THE YEAR ENDED DECEMBER 31, 1977

(Stated in US dollars)

| | Balances as of January 1, 1977 | Additions | Replacements | | Transfers | Balances as of December 31 1977 |
|---|---|---|---|---|---|---|
| | | | Additions | Retirements | | |
| Buildings and constructions in progress | 902,692 | 457,150 | - | - | - | 1,359,842 |
| Research equipment | 357,391 | 140,164 | - | - | - | 497,555 |
| Vehicles and aircraft | 345,533 | 87,543 | 168,948 | 98,086 | - | 503,938 |
| Furniture, fixture and office equipment | 96,266 | 150,243 | 21,689 | 3,652 | 12,366 | 276,912 |
| Operating equipment | 50,263 | 30,383 | - | - | - | 80,646 |
| Installation and Site Development | 203,509 | 355,073 | - | - | - | 558,582 |
| Other | 72,248 | 6,132 | - | 300 | (12,366) | 65,714 |
| | 2,027,902 | 1,226,688 | 190,637 | 102,038 | - | 3,343,189 |

COLDWELL, BANKER & ASSOCIATES

# THE INTERNATIONAL POTATO CENTER - CIP
## DETAIL OF SOURCE OF FUNDS
## FOR THE YEAR ENDED DECEMBER 31, 1977
(Stated in U.S. dollars)

| | | |
|---|---|---|
| CORE OPERATING GRANTS: | | |
| Multi-purpose - | | |
| Danish International Development Agency, Denmark | 256,498 | |
| Swiss Development Cooperation, Switzerland | 180,000 | |
| International Technical Assistance, Netherlands | 250,000 | |
| | 686,498 | |
| Less: | | |
| Applied to earthquake repair | 83,707 | |
| Applied to capital | 132,845 | |
| Applied to working funds | 22,000 | |
| | 447,946 | |
| Core unrestricted grants - | | |
| International Development Agency, Sweden | 462,867 | |
| Overseas Development Ministry, United Kingdom | 222,731 | |
| International Development Agency, Canada | 520,850 | |
| Federal Germany Government | 312,167 | |
| Saudi Arabia | 50,000 | |
| Belgium Government | 59,471 | |
| | 1,628,086 | |
| Plus: | | |
| Balance from previous years | 54,771 | |
| Carry forward from 1976 | 134,488 | 2,265,291 |
| Core restricted - | | |
| Agency for International Development | 1,450,000 | |
| Australian Development Assistance Bureau | 87,992 | |
| Federal Germany Government | 111,277 | |
| Interamerican Development Bank | 457,000 | |
| Belgium Government | 29,735 | |
| | 2,136,004 | |
| Plus: | | |
| Transferred from special project IDRC | 51,990 | |
| Transferred from special project Federal Germany-Training Region V | 2,073 | |
| | 2,190,067 | |
| Less: Payable to Agency for International Development | 66,000 | 2,124,067 |
| | | 4,389,358 |

COLEBIDGE Y ASOCIADOS

## THE INTERNATIONAL POTATO CENTER - CIP

## DETAIL OF SOURCE OF FUNDS

## FOR THE YEAR ENDED DECEMBER 31, 1977

(Stated in U.S. dollars)

| | | |
|---|---|---|
| SPECIAL PROJECT GRANTS - | | |
| International Technical Assistance, Netherlands | 94,000 | |
| Swiss Development Cooperation, Switzerland | 37,500 | |
| International Development Agency, Canada | 54,137 | |
| Ford Foundation | 41,000 | |
| Balance from prior years - | | |
| Ford Foundation | 11,838 | |
| Federal Germany Government-Training Socio Economics | 19,444 | |
| Interamerican Development Bank | 149,346 | |
| International Technical Assistance, Netherlands | (17,338) | |
| Swiss Development Cooperation, Switzerland | 51,569 | |
| International Development Agency, Canada | 26,921 | |
| International Development Research Center | 51,990 | |
| Federal Germany Government, Training Region V | 2,073 | |
| | 522,480 | |
| Less: | | |
| Applied to core restricted | | |
| International Development Research Center | 51,990 | |
| Federal Germany Government | 2,073 | 468,417 |
| CAPITAL GRANTS: | | |
| International Development Association | 945,000 | |
| Interamerican Development Bank | 228,000 | |
| Transferred from multi-purpose funds | 132,845 | |
| | 1,305,845 | |
| Less: | | |
| Deficit 1976 | 73,845 | |
| Aircraft balance | 63,595 | 1,168,405 |
| WORKING FUNDS | | 22,000 |
| OTHER: | | |
| Earned encome, net | | 279,062 |
| | | 6,327,242 |

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EXHIBIT 4

## THE INTERNATIONAL POTATO CENTER - CIP

## SPECIAL PROJECTS FUNDS PROVIDED AND COST

## FOR THE YEAR ENDED DECEMBER 31, 1977

| | Total funds provided | Disbursements | | | Balance to date |
|---|---|---|---|---|---|
| | | Prior years | This year | Total accumulated | |
| Ford Foundation | 127,300 | 115,462 | 9,099 | 124,561 | 2,739 |
| Federal Germany Government | 58,710 | 39,266 | 14,671 | 53,937 | 4,773 |
| International Technical Assistance, Netherlands | 188,000 | 111,338 | 51,727 | 163,065 | 24,935 |
| Swiss Development Cooperation | 112,500 | 23,431 | 51,817 | 75,248 | 37,252 |
| International Development Agency, Canada | 117,871 | 36,813 | 54,292 | 91,105 | 26,766 |
| Interamerican Development Bank | 577,000 | 369,817 | 129,840 | 499,657 | 77,343 |
| Interamerican Development Bank, Overhead | - | 57,837 | 19,476 | 77,313 | (77,313) |
| Ford Foundation | 41,000 | - | - | - | 41,000 |
| The net balance of IDB (Programs A and B) have been covered by a portion of 1977 earned income | 77,313 | - | - | - | 77,313 |
| | 1,299,694 | 753,964 | 330,922 | 1,084,886 | 214,808 |

THE INTERNATIONAL POTATO CENTER
Schedule 1 .- FUNDS PROVIDED AND COSTS
For the year ended December 31, 1977
(US$ Thousand)

| | | Total Funds Available | EXPENSES CHARGED | | | | | | % of Gral. Adm. & Operat. to Direct | Transfer to Unexpended Balance | Payable to Donors |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Fixed Assets | Total Research | Reg. Res. & Training | Library Doc. & Inf. | General Administ. | General Operating (3) | | | |
| Unrestricted Core | (1) | 2,403.4 | | 841.6 | 492.9 | 146.2 | 256.5 | 466.1 | 49 | 198.1 | |
| Restricted Core | | | | | | | | | | | |
| USAID | | 1,450.0 | | 456.7 | 517.6 | 49.9 | 146.9 | 212.9 | 35 | - | 66.0 |
| ADAA | | 88.0 | | | 88.0 | | | - | - | - | |
| Federal Germany | | 113.4 | | | 97.8 | | | 11.7 | 12 | 3.9 | |
| IDB | | 457.0 | | 203.6 | 122.0 | - | 48.0 | 83.4 | 40 | - | |
| Belgium | | 29.7 | | | 23.3 | | | 3.5 | 15 | 2.9 | |
| IDRC | | 52.0 | | 31.6 | | | | 4.8 | 15 | 15.6 | |
| | | 2,1[illegible]0.1 | | 691.9 | 848.7 | 49.9 | 194.9 | 316.3 | | 22.4 | 66.0 |
| Total Operating | | 4,593.[illegible] | | 1,533.5 | 1,341.6 | 198.1 | 451.4 | 782.4 | | 220.5 | 66.0 |
| Capital Grants | | | | | | | | | | | |
| IBRD/IDA | | 945.0 | 945.0 | | | | | | | - | |
| IDB | | 228.0 | 228.0 | | | | | | | - | |
| Unidentified Sources (multi-purpose) | | 132.8 | 132.8 | | | | | | | | |
| Earned Income | | 63.6 | 63.6 | | | | | | | | |
| Balance previous year (deficit) | | (137.4) | (142.7) | | | | | | | 5.3 | |
| Total Capital | | 1,232.0 | 1,226.7 | | | | | | | 5.3 | |
| Special Projects | | | | | | | | | | | |
| Ford Foundation | | 11.[illegible] | | | 9.1 | | | | | 2.7 | |
| Federal Germany | | 19.4 | | | 14.7 | | | | | 4.7 | |
| Netherlands | | 76.7 | | | 51.7 | | | | | 25.0 | |
| Swiss Development Corp. | | 89.1 | | | 51.8 | | | | | 37.3 | |
| CIDA | | 81.1 | | | 54.3 | | | | | 26.8 | |
| IDB | | 207.1 | | | 129.8 | | | | | 77.3 | |
| IDB-Overhead | (2) | (57.8) | | | 19.5 | | | | | (77.3) | |
| Ford Foundation | | 41.0 | | | - | | | | | 41.0 | |
| Earned Income | | 77.3 | | | - | | | | | 77.3 | |
| Total Special Projects | | 545.7 | | | 330.9 | | | | | 214.8 | |
| Earthquake Repair | | | | | | | | | | | |
| Unidentified Sources (multi-purpose) | | 83.7 | | | | | | | | - | |
| Balance previous year (deficit) | | (83.7) | | | | | | | | | |
| | | 0 | | | | | | | | | |
| Working Funds | | | | | | | | | | | |
| Unidentified Sources (multi-purpose) | | 22.0 | | | | | | | | 22.0 | |
| | | 6,393.2 | 1,226.7 | 1,533.5 | 1,672.5 | 198.1 | 451.4 | 782.4 | | 462.6 | 66.0 |

(1) Includes earned income of $ 138,154
(2) IDB overhead have been covered by a portion of 1977 earned income.
(3) Includes TAC Quinquennial Review and five years celebration costs.

THE INTERNATIONAL POTATO CENTER

Schedule 2 .- DETAILED SCHEDULE OF EARNED INCOME

For the year ended December 31, 1977
(US$ Thousands)

| | Approved Budget | Actual |
|---|---|---|
| **Sources of Earned Income** | | |
| Interests on Deposits | 5.0 | 3.7 |
| Sales of Crops & Materials | 2.0 | 1.0 |
| Sale of Fixed Assets | 25.0 | 113.8 |
| Indirect Costs charges on Special Projects & Current Accounts | 70.0 | 45.6 |
| Adjustment prior year | 4.0 | 4.2 |
| Rate of exchange adjustment & other | 6.0 | 57.6 |
| | 112.0 | 225.9 |
| Plus : Aircraft estimated rent | 23.0 | 63.6 |
| | 135.0 | 289.5 |
| Less : Auxiliary Services Deficit | 10.0 | 10.4 |
| | 125.0 | 279.1 |
| **Application of Earned Income** | | |
| Applied to Core Operations | 27.0 | 138.2 |
| Applied to Capital | 23.0 | 63.6 |
| Applied to Special Projects | 75.0 | 77.3 |
| | 125.0 | 279.1 |

THE INTERNATIONAL POTATO CENTER
Schedule 3 .- COMPARATIVE STATEMENT OF ACTUAL EXPENSES
AND APPROVED BUDGET FOR THE YEAR ENDED DECEMBER 31, 1977
(US$ Thousands)

| | CORE Unrestricted | | CORE Restricted | | CAPITAL | |
|---|---|---|---|---|---|---|
| | Budget | Actual | Budget | Actual | Budget | Actual |
| Programs | | | | | | |
| Potato Research | | 841.6 | | 691.9 | | |
| Regional Research & Training | | 492.9 | | 848.7 | | |
| Library, Doc. & Info. Services | | 148.2 | | 49.9 | | |
| General Administration | | 256.5 | | 194.9 | | |
| General Operating Costs | | 420.8 | | 262.7 | | |
| TAC Quinquennial Review and five years celebration | | 45.3 | | 53.6 | | |
| | 2,389.0 | 2,205.3 | 2,125.0 | 2,101.7 | | |
| Capital | | | | | | |
| Operating Equipment | | | | | 23.0 | 30.4 |
| Research Equipment | | | | | 162.0 | 140.2 |
| Installation & Utilities | | | | | 211.6 | 372.3 |
| Furnitures, Fixtures & Off. Equip. | | | | | 108.9 | 155.9 |
| Vehicles & Aircraft | | | | | 68.5 | 37.5 |
| Constructions & Buildings | | | | | 620.4 | 457.2 |
| Site Development | | | | | 37.2 | 37.8 |
| Other | | | | | .4 | .4 |
| | | | | | 1,232.0 | 1,226.7 |
| Analysis of Variances | | | | | | |
| Budget Surpluses : | | | | | | |
| Unexpended Balance | | 198.1 | | 22.4 | | 5.3 |
| Payable to Donors | | | | 66.0 | | |
| Unbudget Additional Income | 14.4 | | 65.1 | | | |
| Deficits : | - | - | - | - | - | - |
| | 2,403.4 | 2,403.4 | 2,190.1 | 2,190.1 | 1,232.0 | 1,232.0 |