Farmer Management of Potato Insect Pests in Peru

Peter Ewell, Hugo Fano, K.V. Raman, Jesús Alcázar, María Palacios and Javier Carhuamaca

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Report of an Interdisciplinary Research Project in Selected Regions of the Highlands and Coast

Peter T. Ewell, Hugo Fano, K.V. Raman, Jesús Alcázar, María Palacios and Javier Carhuamaca

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Authors:

P. Ewell and H. Fano, Economists and K.V. Raman, J. Alcázar, M. Palacios, Entomologists, International Potato Center (CIP), P.O. Box 5969, Lima, Perú; J. Carhuamaca, Entomologist, Peruvian National Potato Program.

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Abstract

Potatoes are a high-value, perishable crop with high production costs. Farmers in Peru, as in the rest of the world, rely increasingly on chemical pesticides. Interdisciplinary field research was carried out in three regions where pesticide use has increased rapidly. Work focused on farmers' practices for the control of three major pests: Andean weevil (*Premnotrypes spp.*), potato tuber moth (*Pthorimaea operculella* (Zeller) and *Symmetrischema plaesiosema* (Turner)) and leaf miner fly (*Liriomyza huidobrenzis* Blanchard).

The farmers in the sample recognized all of the major insect pests although they used a diversity of local names for them. Their pest management strategies included direct control practices, the indirect effect of long rotations, cultural practices, and chemical insecticides. The latter were found to be the most widely used of all purchased inputs, although the quantities applied and the total cost varied over a wide range. Advertising by multinational firms and the advice of salesmen and local merchants have been far more effective in providing timely information than the government's research and extension services. Certain products and application practices have become widely adopted, even though there is good evidence that these are neither the most effective nor the most economical technologies which could be used.

Integrated pest management (IPM) can only become a reality if various component technologies are taken up by farmers and combined and adapted according to their own conditions. Interdisciplinary research and extension are required to provide farmers with better components and to help adapt them to local circumstances. On-farm research -- surveys, on-farm monitoring, and on-farm experiments-- have important roles to play. This study has brought these elements together in an attempt to learn about farmers' management of three important insect pests, and to explore methods for incorporating the user's perspective into entomological research.

Resumen

La papa es un cultivo perecible de mucho valor y de costos de producción muy altos. Los agricultores en el Perú, al igual que en el resto del mundo, confían cada vez más en los insecticidas químicos. Se llevó a cabo una investigación interdisciplinaria de campo en tres regiones donde el uso de pesticidas se ha incrementado rápidamente. El trabajo se enfocó a las prácticas de los agricultores para el control de tres plagas importantes: el Gorgojo de los Andes (*Premnotrypes spp.*), las polillas del tubérculo de la papa (*Pthorimaea operculella* (Zeller) y *Symmestrichema plaesiosema* (Turner)) y las mosca minadora de la hoja (*Liriomyza huidobrensis* Blanchard).

Los agricultores en la muestra reconocieron todas las plagas principales aunque utilizaban diversos nombres locales para ellas. Sus estrategias para el manejo de las plagas incluían prácticas de control directo, el efecto indirecto de prolongadas rotaciones, prácticas culturales e insecticidas químicos. Se encontró que los últimos eran los más ampliamente utilizados de todos los insumos adquiridos, aunque las cantidades aplicadas y el costo total variaron en un amplio margen. La publicidad de firmas multinacionales y las recomendaciones de vendedores y comerciantes locales han sido mucho más efectivas en proveer información oportuna que los servicios de investigación y extensión del gobierno. Algunos productos y prácticas de aplicación han resultado ampliamente adoptados, aún existiendo buena evidencia de que éstas no son las tecnologías más efectivas ni las más económicas que puedan utilizarse.

El manejo integrado de plagas (IPM) puede solamente convertirse en realidad si varios componentes tecnológicos son adoptados por los agricultores y son combinados y adaptados de acuerdo con sus propias condiciones. Se requiere de investigación y extensión interdisciplinarias para proveer a los agricultores con mejores componentes y para ayudar a adaptarlos a las condiciones locales. Las investigaciones en fincas --estudios, seguimientos y experimentos-- juegan un papel importante. Este estudio ha reunido estos elementos en un intento por aprender sobre el manejo que los agricultores hacen de estas tres importantes plagas y para explorar métodos que incorporen la perspectiva de los usuarios a la investigación entomológica.

Introduction

Potatoes are a high-value, perishable crop with high production costs. They are attacked by a broad range of insect pests and diseases, both in the field and in storage. Agricultural practices of small potato farmers throughout the Third World include a range of strategies to deal with pests. The use of chemical pesticides is increasing rapidly, particularly where farmers are intensifying production methods in order to be able to sell in urban markets, and where the crop is expanding into agroecological regions and planting seasons outside of its traditional range. Pesticides, which can be very effective in the short run, are increasingly used by farmers as a kind of insurance to protect investments in seed, fertilizers, hired labor, and other input costs.

Nevertheless, it is widely recognized that reliance on chemicals alone is not a sustainable control strategy. Pest populations develop resistance, their predators, parasites, and other natural control mechanisms are disrupted, and new pests appear. Costs go up as farmers apply ever higher doses of ever more expensive pesticides. A bewildering diversity of chemicals is aggressively promoted by multinational agrochemical companies, national distributors, and local outlets. Nevertheless, reliable information on how to prepare, mix, and apply pesticides is not widely available. Many products are dangerous to handle and store, and their residues often have serious long-term effects on public health and on the environment (Brader, 1979; Cisneros, 1984).

Integrated pest management (IPM) provides a framework for the development of technologies which, when combined in ways appropriate to the farmers' conditions, can reduce insecticide use. Applied entomological research at CIP is focused on component technologies to aid in the control of pests that cause significant losses to large numbers of farmers in many countries. Research activities, both at CIP and in collaboration with national programs and universities, cover the following areas:

- screening of genetic material for resistance and tolerance as part of the breeding of new varieties,
- identification of predators and parasites for biological control and the testing of their effects,
- identification, synthesis, and field testing of pheromones for monitoring and mass trapping, and
- manipulation of the field and/or storage environment with modified cultural practices to affect population or behavior of the pests.

Promising technologies developed by CIP are being tested and adapted by national programs as they develop IPM programs for specific conditions.

A major strategy at CIP is to bring farmers' perspectives into all phases of the research process, through the interdisciplinary cooperation of natural and social scientists. Integrated pest management programs require much more information about the natural, socioeconomic, and institutional environment within which farmers operate than does

reliance on pesticides for "quick solutions." In most cases, IPM programs have been developed as a solution to dramatic problems arising after years of excessive pesticide use.

There is growing interest in starting from the "users' perspective:" from the documentation and analysis of farmers' control strategies, both their traditional methods and their use of pesticides. This knowledge can then serve as a basis for the development of appropriate IPM systems before pest problems lead to the excessive use of pesticides (Altieri, 1984; Brown, 1986; Glass and Thurston, 1978; Matteson, Altieri and Gagne, 1984; Tait, 1987).

This report summarizes the results of two years of interdisciplinary research carried out by social scientists and entomologists from CIP, with the cooperation of the Peruvian National Potato Program.[1] The work started with diagnostic surveys to identify farmers' perceptions of their pest problems and current control practices. Then more detailed surveys, combined with on-farm monitoring and experiments, were developed to analyze farmers' pest control practices in more detail.

The work focused on three important insect pests of potatoes:

- The Andean weevil (*Premnotrypes spp.* (*Coleoptera: Curculionidae*)) is an endemic pest throughout the South American highlands.
- Two species of potato tuber moth, *Pthorimaea operculella* (Zeller) and *Symmetrischema plaeseosema* (Turner) (*Lepidoptera: Gelechiidae*), are increasingly serious problems in stores.
- The leaf miner fly (*Liriomyza huidobrensis* Blanchard (*Diptera: Agromyzidae*)) has become a major pest on the coast due to the over-use of pesticides on potatoes grown under irrigation.

The paper is divided into six major sections, each recounting a different phase of the research program. The first outlines the problem of increasing pesticide use in potato production in Peru, and identifies the particular areas where surveys and experimental research were carried out. The second reports the results of a diagnostic survey of pest problems and farmers' control practices in two areas of the highlands. The third reports the results of coordinated surveys and experiments on the Andean weevil in the Mantaro Valley. The fourth reports a study of potato tuber moth in the stores of a sub-sample of the same farmers. The fifth reports two seasons of interdisciplinary research on the leaf miner fly in the Cañete Valley on the coast. A final section of summary and conclusions draws together lessons for further research.

1. The national potato program of the Instituto Nacional de Investigaciones Agrícolas y Agroindustriales (INIAA) is headquartered in Huancayo.

1. Intensification of Potato Production and Pesticide Use in Peru

In Peru, most potato farmers grow the crop for two purposes: to satisfy household food needs, and to generate cash income. Potatoes were first domesticated in the region surrounding Lake Titicaca, and have been grown for centuries under a wide range of conditions in the heterogeneous, mountainous environment. Most of the crop is produced under rainfed conditions, at high altitude, and on steep slopes. The risks of damage or loss from the many pests and diseases which have evolved with potatoes --as well as from frost, hail or drought-- are very high[1]. Peasant agricultural systems have evolved ways of dealing with these risks, but conditions are marginal and national average yield of about 8 t/ha is less than 60 percent of the world average of 15 t/ha (Horton, 1988).

According to figures reported to the FAO, the area in production in Peru declined from 255,000 hectares in 1960-63 to 172,000 hectares in 1983-85 as marginal lands have been taken out of production (Horton, 1988). Nevertheless, total annual output has remained about constant, at 1.4 million tons, because average yields increased from 6 to 8 t/ha over the same period.

This increase can be explained by the fact that farmers in certain areas have intensified their production methods to supply rising demand in rapidly growing cities. They have adapted modern varieties, chemical fertilizers, and other new technology to their conditions, in combination with many long-established practices, and routinely harvest between 20 and 30 t/ha (Fano, 1983). This process of technical change has been associated with widely diffused and rapidly increasing use of pesticides (Peralta and Javier, 1980). The total of 241 farmers interviewed in the course of this study between 1984 and 1986 reported the use of 46 different insecticides and 18 different fungicides (Appendix Table 1).

Study regions

Field research was carried out in three regions where potato agriculture has been intensified and pesticide use has increased dramatically over the past generation: (1) Cuzco in the southern highlands, (2) the Mantaro Valley in the central highlands, east of the city of Lima, and (3) the irrigated Cañete Valley on the coast. The study areas were selected where CIP's Social Science Department had previously collected and published baseline information about the predominant production systems (Map 1).[2]

1. There are a number of general surveys of potato pests in Peru (Alcalá, 1981; Cáceda and Rossel, 1984; Valencia, 1984; Wille, 1952.
2. The results of a socioeconomic survey of potato farmers in Cuzco was published in 1983 (Franco, Moreno, and Alarcon, 1983). The Mantaro Valley was the site of a sequence of interdisciplinary research projects from 1977 to 1981, the results of which have been summarized by Horton (Horton, 1984). Various studies have dealt with different aspects of potato production in the Cañete Valley (Monares, 1979; Scott, 1985; Rhoades et al., In preparation).

Map 1. Research zones in Peru

Cuzco

Cuzco was the ancient capital of the Inca empire and remains an important center of indigenous peasant population and traditional agricultural practices. Most farmers are members of diversified peasant households. They grow many crops both for home consumption and for the market, and supplement their incomes with off-farm labor. Potatoes are the major staple in their diet, and are also their most valuable cash crop. They concentrate on the potato crop whatever they can afford to spend on fertilizers, pesticides, and other purchased inputs. Nevertheless, resources are limited and average yields are low --between 2 and 10 t/ha depending on the region (Franco, et al., 1983).

The Mantaro Valley

The largest of the interandean valleys in the central highlands, the Mantaro Valley is a major supplier of potatoes for consumption in the Lima market. The area is also a major source of seed for commercial growers on the coast (Scott, 1985). Although they continue to produce potatoes for home consumption, almost all small farmers have selectively adopted modern varieties and use purchased inputs, and achieve yields between 20 and 35 t/ha on small hillside plots. On good valley bottom lands, medium and large farmers harvest as much as 50 or 60 t/ha in favorable years.

The Cañete Valley

Cañete is an irrigated valley on the central coast. Historically, large estates specialized in the production of sugar cane and cotton for export. Irrigated potato production in the cool winter season has expanded rapidly since the 1950's to supply the market in Lima. Medium-sized farmers with between 5 and 50 hectares in production are able to market potatoes in those months when supply from the highlands is short, and prices tend to be good. Yields average 20 to 30 t/ha. Production is mechanized and high levels of purchased inputs are applied.

2. Pest Management Practices in the Highlands

The first stage of the research project was a single-visit survey in Cuzco and the Mantaro Valley in the 1984-85 growing season. The goal was to identify the key characteristics of farmers' pest management strategies which change as production methods are intensified.

Characteristic strategies of the farmers sampled

Using CIP's previous studies as a sampling frame, 85 farmers were selected to represent the range of altitude zones and farm sizes in approximately their true proportions (Appendix Figure 1). Most of the farms were small, with less than two hectares in cultivation and less than one hectare of potatoes. Seventy percent of the farmers owned their land; the other thirty were about evenly divided between rentals, sharecropping arrangements, and customary access to communal resources. The sample was designed to provide a cross section of the range and variability of pest management practices.

The single most significant environmental factor in Andean agriculture is altitude. Although variations in the orientation of the slopes and in the rainfall are important on a local scale, the following pattern is dominant in the two zones. Potato production is concentrated in a band between 3,000 and 4,300 meters above sea level. The natural grasslands above 4,000 meters, called the *puna*, are used primarily for grazing animals. Native, frost-resistant varieties of potatoes are grown in small plots, particularly for transformation into the traditional freeze-dried food *chuño*. Yields are low and uncertain.

Moving down the slopes, concentrated areas of increasingly intensive potato production are found between 4,000 and 3,500 meters. The warmer, drier areas at lower elevations are used for earlier plantings, particularly in naturally moist patches or where supplemental irrigation is available.

Farm households commonly cultivate six, eight, or even more widely separated plots simultaneously. The altitude, planting date and management practices vary significantly between plots. A number of crops are grown, but in most cases potatoes are the most valuable cash commodity in which farmers invest whatever cash inputs they can afford. It is common to use traditional varieties and pest management practices on plots planted with native landraces for home consumption, and to apply pesticides heavily on plots planted with commercial varieties destined for sale.[1]

1. In Peru, it is impossible to make a consistent distinction between "traditional" or "native" landraces on the one hand, and "modern," "hybrid", or "improved" varieties on the other. Hybrid clones produced by breeding programs over the past generation are often found in intervarietal mixtures in plots at high

Position Paper

Farmers' perceptions of principal pests

As the first part of each interview, we asked the farmers to identify the insects, diseases, and abiotic stresses affecting their potato crop. They call the pests by highly localized names. A box of insect specimens with pinned adults and larvae in alcohol proved a very useful survey tool (Fano and Ewell, 1986). The whole family would quickly gather to look at the specimens, and would talk freely about control methods they had tried or heard about. We soon learned that some farmers are far more observant of insects than others, and that older people, especially women, made the best informants. Children made enthusiastic assistants to collect new specimens for the collection.

Local names

The first output was a glossary of the most common local names for the pests (Appendix Table 2). The terms used vary over short distances (Fano, Alcazar, and Palacios, 1985). The most common term for the Andean weevil, papakuru, simply means "potato worm" in the local Quechua language. Some terms describe the appearance of the insects: yanakata means "black cloak" and well describes the large black beetles *Epicauta spp.*, Gusano arroz, or "rice worm", is a good description of the size and shape of weevil larvae. Insects that are not recognized specifically, or which cause little damage are called simply "pests": kuru in Quechua or gusanos in Spanish. Technical people often criticize peasant farmers for their ignorance, without taking the time to learn the vocabulary with which the results of their detailed empirical observations are expressed.

Farmers' rankings of pest problems

Once we were sure that we were talking about the same pests, we asked the farmers to assess the importance of the insects and other problems that affected their crop in the most recent growing season. The informants rated the various risks from 0, for not a problem, to 3, for a serious constraint. We also noted how many farmers could identify each specimen with a name and a coherent explanation of the kind of damage it causes (Table 1).

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elevation planted for home consumption. Certain landraces with deep eyes, highly pigmented, flesh, and other "traditional" characteristics are grown by relatively large farms for the market using intensive technology, and they fetch premium prices.

Table 1. Farmers' ranking of principal pest problems in Cuzco and the Mantaro Valley, 1985-86

Pest	Average rank[1] (1-3)	Percent of farmers who recognized specimen[2]
1. Andean weevil, *Premnotrypes spp.* (larvae)	2.4	100
2. Soil worms (primarily of the family *Noctuidae*)	2.4	100
3. Fungus diseases (primarily *Phytophthora infestans*)	2.3	--
4. Potato tuber moth, *Phthorimaea operculella* (Zeller)	2.0	91
5. Flea beetle, *Epitrix spp.* (adults)	1.9	100
6. Stem borers, *Symmetrischema plaesiosema* (Turner), *Stenoptycha sp.*	1.9	65
7. Blister beetle, *Epicauta spp.*	1.7	100
8. Flea beetle, *Epitrix sp.* (larvae)	1.7	78
9. Andean weevil, *Premnotrypes spp.* (adults)	1.4	68
10. Viral diseases	1.4	--
11. Nematodes	1.3	60
12. Diabrotica, *Diabrotica spp.*	1.1	57
13. Aphids, *Myzus persicae* (Sulzer)	1.0	75
14. Slugs, *Helix spp.*	.9	75
15. Leafhoppers, *Empoasca spp.*	.6	85
16. Thrips, *Frankliniella tuberosi* Moulton	.6	43

1. Mean score of farmers' assessments of relative severity in 1984-85 season: 0 = not a problem, 1 = slight problem, 2 = moderate problem, 3 = serious problem.
2. Percent of farmers who could provide some name for a specimen of the insect, and describe its damage.

Source: Interviews with 74 potato farmers in Junin and Cuzco, Peru.

Most of the informants cited natural hazards --frost, hail, and drought-- and uncertain prices as equal or more serious sources of risk than any single pest. Five pests --Andean weevils, soil worms, fungus diseases, potato tuber moth, and flea beetles-- are significant problems in most areas in most years and are the focus of farmers' pest control practices. In general, insects were reported to be the more serious problem in drier regions, droughty years, and in irrigated fields during the dry season. Fungus diseases are the more serious problem under wetter conditions[2].

2. This study concentrated on insect pests and did not look at diseases in any systematic way. The major fungal disease is late blight (*Phytophthora infestans*), which occurs in complex associations with other pathogens. A variety of diseases attack potatoes in storage. The study did not cover the rainier, eastern slopes of the Andes. The development of varieties with partial tolerance to late blight has extended the range of commercial potato production into these areas, where farmers can plant and harvest early to get the benefit of high seasonal prices. Nevertheless, diseases are a major problem and the farmers must repeatedly spray with fungicides, which constitute a significant proportion of the costs of production (Mayer and Glave, In Prep.).

Some insects are more familiar to farmers than others. For example, all the informants could provide some local name for blister beetles (*Epicauta spp.*), a large and highly distinctive insect, although it causes serious damage only in occasional years. Small, relatively inconspicuous organisms, such as leafhoppers and thrips, which cause more frequent but less conspicuous damage, were less widely recognized. Farmers tended to give higher rank to problems they had seen recently, at the time of the interview.

Few farmers could accurately distinguish between various *lepidopteran* larvae or match them up with their adult forms. Only large producers with intensive management practices and access to technical information from agrochemical companies and government agencies could correctly identify nematode damage. The symptoms of nematodes damage and of diseases are often interpreted by farmers as the results of poor soils or unfavorable weather. The role of insects as vectors for diseases, and the identity and habits of predatory and parasitic beneficial insects, do not seem to be part of common traditional knowledge. These conclusions are in line with findings in other parts of the world (Richards, 1980; Kenmore, et al., 1987).

Pest management strategies

Once the major pests were identified, we applied a brief questionnaire about the methods used for their control. Farmers' practices for reducing risks of pest losses can be classified according to the following simple typology:

- Rites and ceremonies
- Control methods with direct effects
- The organization of the cropping system
- Cultural practices
- Pesticides

Rites and ceremonies

Religious and magical rites and ceremonies are universal in peasant societies. Their use in an attempt to avoid pests and other risks is an interesting area which fell outside the scope of this study.

Control methods with direct effects

A number of traditional practices are carried out specifically for the control of pests. One example is the placement of aromatic plants on or near stored potatoes, both as a barrier and as a repellent. About a third of the farmers in our sample reported the use of the local weed *Muña* (*Minthostachys sp.*) in their stores; a smaller number were using eucalyptus

leaves, hot peppers, and other plants. CIP has been testing the effectiveness of a broad range of repellent weeds in various parts of the world (Raman and Booth, 1984). Other examples of direct control include the application of lime or ashes around the base of young plants to control soil worms and slugs (Altieri, 1984), the release of baby chicks in fields during weeding to find and eat insect larvae, and the placement of physical barriers around stores.

The organization of the cropping system

The way agricultural production is organized can have important indirect effects on pest populations. For example, families in highland communities have historically obtained access to land for planting within a system of sectorial fallow. A community is divided up into some number of sectors, classically eight. Land in each sector is allocated among all eligible families.

In year one, everybody breaks sod within one single sector and plants potatoes. In year two, everybody plants that same sector with the next crop in the rotation --either the native tuber crops *oca* (*Oxalis tuberosa*), *olluco* (*Ullucus tuberosus*), or *mashua* or *añu* (*Tropaelum tuberosum*) or a small grain, usually barley. At the same time, they break fresh sod and plant potatoes in a second section. In the ideal system, each section is cultivated for three years and then reverts to grass fallow, which is grazed for three or four years before its turn to be planted with potatoes comes around again (Mayer, 1979; Yamamoto, 1985).

This community-controlled rotation system makes it relatively easy to keep unfenced grazing animals away from the compact blocks of crops. It also enforces a long fallow between potato crops, reducing the risk of nematodes and other pests that persist in the soil, even though farmers do not understand the mechanism of this benefit. As farmers increase the area planted in order to market their output, community control breaks down. Sectorial fallow systems survive primarily at high elevations, where traditional native varieties are planted.

The diversification of traditional agriculture also protects farmers against risks. Individual farm households commonly plant crops in four or five or as many as 12 or 15 widely separated plots. This allows them to take advantage of different micro-climates and planting seasons. It also ensures that at least some plots will survive until the harvest. The climate is harsh and losses are frequent, but the traditional organization of production provides a certain security in a highly risky environment.

Cultural practices

Many cultural practices tend to lower pest populations and/or reduce their economic damage. Examples include the choice of planting date to avoid periods of high infestation, and high hilling to prevent insect larvae from finding their way down to the tubers.

Potatoes are rarely intercropped with other crops in the highlands of Peru, except along the lower boundaries of the altitude zone where they are grown, between 2,000 and 2,500 meters. Nevertheless, farmers traditionally interplant from five to as many as 30 or more different varieties of potatoes in the same field (Brush, Carney, and Huamán, 1981). This is done primarily to provide diversity in a diet that depends heavily on potatoes as a staple. Nevertheless, traditional varieties have different tolerances to diseases and frost, so genetic variability within plots reduces risk of catastrophic loss.

Use of pesticides

The use of pesticides has increased rapidly since they were first introduced in the late 1940's. Over this period, improved varieties, fertilizers, and other innovations have increased yields in high-capacity areas with access to markets. At the same time, both the risks of pest attack and the financial consequences of pest damage have gone up significantly.

As fallow periods are reduced and potatoes are produced more intensively, two things happen. First, pests in a given area have more continuous access to sources of food, and their populations tend to increase. Second, the pests threaten crops in which the farmers have already made significant expenditures for improved seed, fertilizers, labor, and other input costs. An additional expenditure on pesticides becomes a kind of insurance, to protect the investments which have been made in the course of the growing season. It is within this shifting and heterogeneous context that chemical pesticides have been widely adopted over the past 40 years (Peralta and Javier, 1980).

Pesticides are aggressively promoted in rural Peru by a network of multinational corporations and local distributors. Several products freely available in local outlets are banned or severely restricted in their countries of origin. These include organochloride insecticides such as Aldrin, which are highly persistent and build up in the food chain. Nevertheless, their acute toxicity to people handling them directly is quite low, and they are relatively inexpensive. They have been replaced by organophosphates and carbamates which break down quickly, but which are both more dangerous to handle and more expensive.

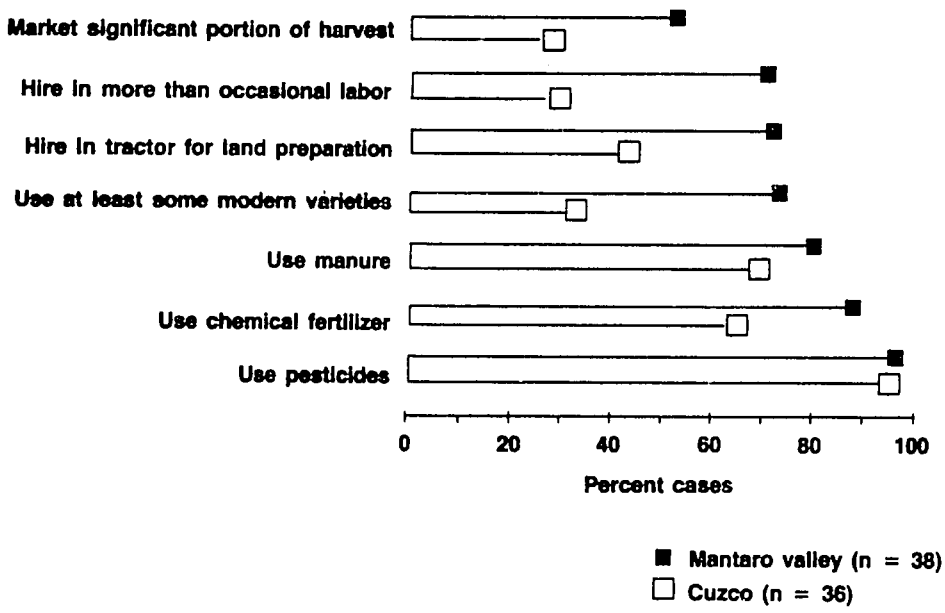
In Peru, whole families go out into the fields together to plant potatoes. It is common to see children use their bare hands to apply Furadan (Carbofuran). Although dangerous handling procedures were frequently observed, this study did not include systematic research on health or safety issues.

Pesticides, the most widely used purchased input

Data from the survey shows that inputs of all kinds are used more intensively in the more commercially-oriented Mantaro Valley than in Cuzco. Nevertheless, the differences consist in different frequencies of certain practices within the same general context of mixed

subsistence-commercial potato production, and do not reflect completely different production systems (Figure 1).

Figure 1. Mantaro Valley and Cuzco: Selected characteristics of production systems of sample farmers. 1984-85



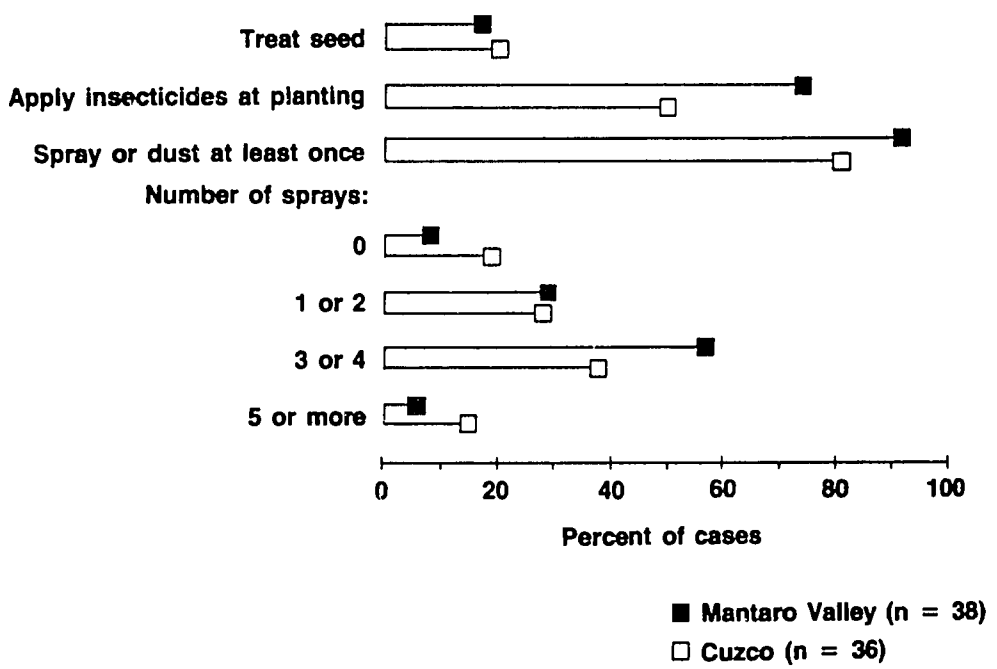
Over a quarter of the farmers sampled in the Mantaro Valley grew the crop primarily for home consumption. Nearly a third of those in Cuzco marketed a significant proportion of their harvest. There were notable differences between the regions in the use of hired labor, the use of tractors for land preparation, and the planting of at least some modern varieties. Manure is usually obtained on the same or nearby farms, and is not usually purchased. Even so, 88 percent of the sampled farmers in the Mantaro Valley and 64 percent of those in Cuzco applied additional chemical fertilizers. Chemical pesticides were the most commonly-used, purchased input, reported by 97 and 94 percent of the farmers in the two regions respectively.

Although virtually all the farmers applied at least some pesticides, the products used, the rate and frequency of application, and the costs varied significantly. At one extreme, a farmer in Cuzco made a single application of Aldrin dissolved in a can, splashing it on with a home-made brush made of twigs, at an estimated cost of about US$ 18 per hectare. At

the other extreme, a large seed producer in the Mantaro Valley applied *Curater* (Carbofuran) at planting and then sprayed the crop 10 times with various mixtures of insecticides, fungicides, and foliar fertilizers. The total estimated cost in products alone was over US$ 1,300 per hectare.

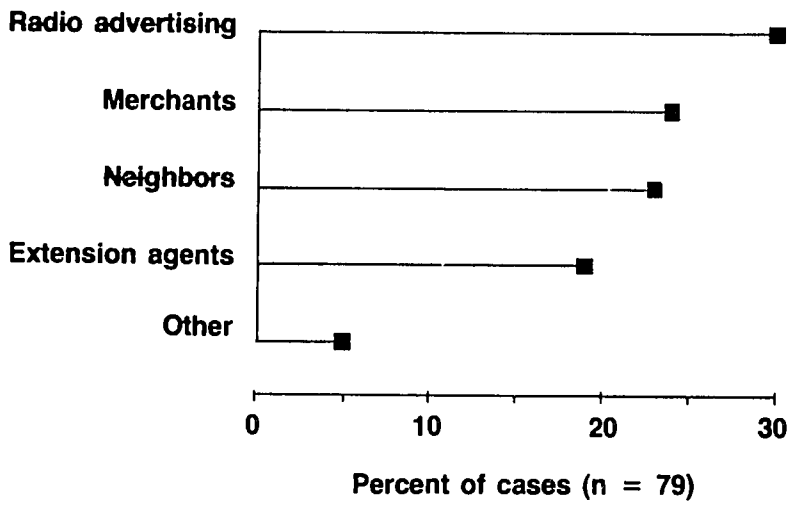
Pesticide use patterns differ between the two regions (Figure 2). Fewer than 20 percent of the farmers in both areas treated their seed with fungicides before planting. Seventy-four and 50 percent applied insecticides to the soil at the time of planting. This is the principal method used for the control of Andean weevil (*Premnotrypes spp.*), a problem discussed in more detail below. Ninety-two and 81 percent of the farmers dusted or sprayed the plants at least once; most made applications between one and four times. Farmers commonly mixed different products together: insecticides for whatever pests were causing visible damage to the leaves, fungicides for late blight and other diseases, and foliar fertilizers which they believe help the plants recover from frost, hail, or other physical damage. They used the products that were available, which were not always the most appropriate chemicals or dosages for their particular problem.

Figure 2. Mantaro Valley and Cuzco: Use of pesticides by sample farmers. 1984-85



The most important source of information about new products, cited by nearly one third of the farmers, was radio advertising by the chemical companies. The next was the recommendations of the merchants in the outlets where they buy, followed by the advice of neighbors (Figure 3).

Figure 3. Mantaro Valley and Cuzco: Sources of Information about Pesticides Cited by Sample Farmers. 1985

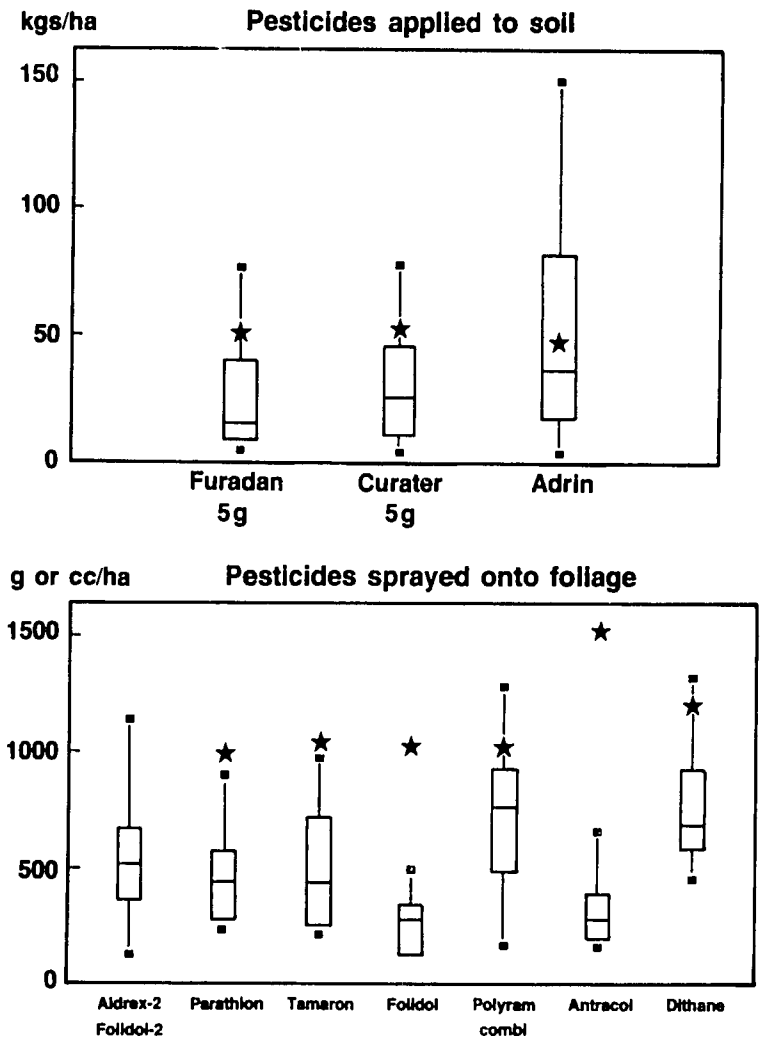


The government's research and extension service has not been able to provide clear alternatives to the technology developed and marketed through the private sector. Although extensionists were consulted by 19 percent of the farmers, the information they offered came primarily from the distributors of pesticides.

During the period of the study, the prices of imported inputs relative to the value of the output, rose in a climate of inflation and uncertainty. Farmers tended to apply less than the recommended dosage of individual products to save money (Figure 4). At the same time, they often mixed different products of the same type, causing over-dosing and waste.

It is common for both researchers and extension personnel to assert that small farmers are ignorant about pesticides -- that they do not, for example, understand the difference between insecticides and fungicides. We found in this study that, on the contrary, farmers generally have a very good understanding of the basic chemical armory, particularly products that have been on the market for some time. They may get mixed up about names in talking about them, but rarely make mistakes in practice. Farmers have observed carefully, and adjusted their use of pesticides in light of their own conditions. Nevertheless, our preliminary diagnostic survey documented a serious need for more research and extension to provide more effective, safer, and more cost-effective pest management methods. The next stage of the research consisted of more detailed field studies focused on the most widely distributed and serious insect pests.

Figure 4. Peru: Application rates of selected pesticides reported by highland farmers. 1984-85



★ Manufacturer's recommended application rate

Note: These "box-and-whisker" charts are constructed as follows. The horizontal in the middle of each box is the median. The box runs from the lower to the upper quartile. The vertical lines extend out to the extreme observations, marking the range. The stars indicate the manufacturers' recommended application rates package labels.

3. Andean Weevil: An Endemic Pest in the Highlands

Several weevils in the genus *Premnotrypes* are the most important insect pests of potatoes throughout the Andean region. They damage tubers in the field, particularly at higher elevations, and also in stores. The logic, effectiveness, and cost of farmers' pest control practices were investigated in an interdisciplinary project in the 1985-86 growing season.

The field research was built up of several inter-related parts. A sample of 68 farmers was interviewed several times during the growing season, and detailed data on their pest management practices were recorded. Damage to the tubers at the moment of the harvest was monitored directly in a sub-sample of 51 fields. More detailed data on a few key variables were provided by an experiment carried out in a farmer's field by entomologists from CIP. Data collection methods were coordinated with two student thesis projects, and with an on-going pest monitoring project of the Peruvian national potato program. The field project was originally designed to analyze the patterns of field infestation of potato tuber moth (*P. operculella* and *S. plaesiosema*). Rainfall was well above average through the growing season. Essentially no tuber moth damage was found, and infestations of Andean weevil were relatively light.

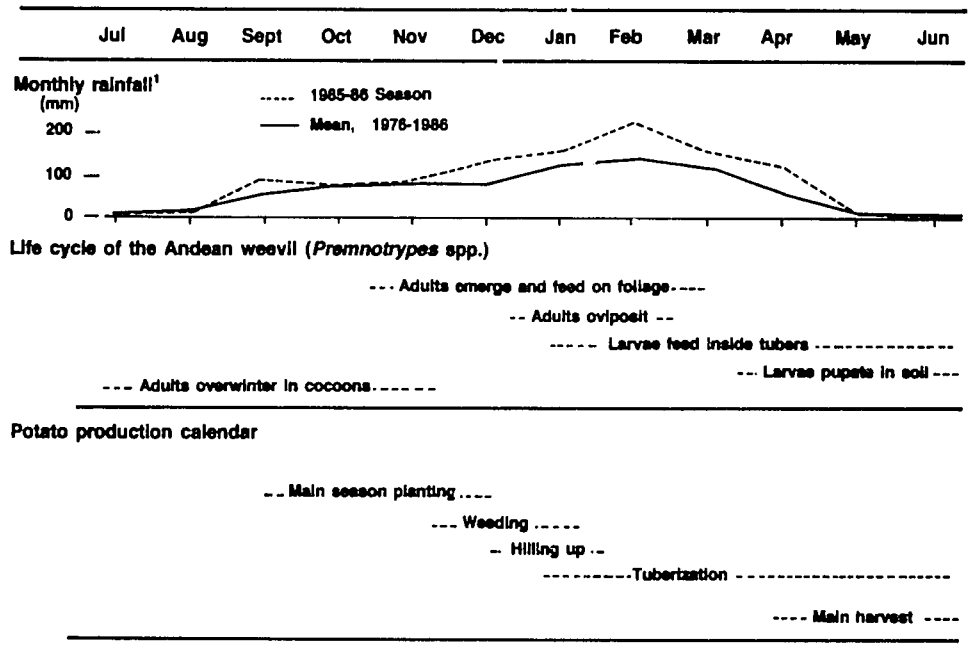
Life cycle of the weevil and the production calendar of the crop

Both of the major weevil species in Peru, *P. suturicallus* Kuschel, and *P. latithorax* (Pierce), go through one complete generation a year (Alcalá and Alcazar, 1976; Carrasco, 1961; Valencia, 1984) (Figure 5).

The annual rainfall pattern, the annual calendar of potato production, and the cycle of the weevil are closely related. Early plantings tend to avoid the period of worst infestation from April through June, but this practice is only possible in moist areas, or where irrigation is available. Another problem is that the insects pass most of their lives underground.

The adults begin to emerge from the soil starting at the beginning of the rainy season, in October and November. The insects --black or earth-colored, between seven and eight millimeters long-- search for young potato plants as a source of food. They move in from the edge of a field towards the center. The weevils hide under small clods of dirt during the day, and feed on the leaves at night. Potato plants usually grow fast enough to compensate for this damage to their leaves, which normally has no effect on final yields.

Figure 5. Mantaro Valley: Annual rainfall pattern, life cycle of the Andean weevil, and potato production calendar



[1]Data from the Peruvian Geophysical Institute in Huayao, Mantaro Valley.

The population of adults in a given area varies considerably from one year to another depending on rainfall, temperature, the cropping history of the field, and other factors. Trapping studies have found numbers at their highest in January and February (Meza Rojas, 1978). Studies have documented their life cycle (Appendix Table 3). The insects are sexually mature at the time of emergence, and the females lay their eggs under dead vegetation around the base of the plants. The larvae hatch approximately 30 days later. They quickly find and burrow into young tubers, which are just being formed at this time. The larvae pass through four larval stages, or instars, and spend a total of between 40 and 50 days inside the potatoes. They burrow serpentine tunnels through the flesh, in which they leave trails of blackish excrement.

The larvae move back out into the soil to pupate. Fully formed adults overwinter in their cocoons through the dry, cool months, until they emerge at the beginning of the next rainy season to begin the cycle again.

Andean weevils can cause significant damage to the crop in the ground, particularly if the harvest is delayed, which gives the insects more time to find and burrow into the potatoes. Losses tend to be patchy, even within single fields, and damage levels are highly

variable. Generally speaking, damage is more serious in relatively dry years, particularly when a droughty period comes late in the season. Larvae can be carried in the tubers into stores, where they cause further damage. Under some conditions, weevils pupate in large numbers below or near storage structures, areas which may become foci of infestation in the subsequent season (Yábar, 1988).

Control methods

Traditional strategies of tolerance

Under extremely unfavorable conditions, field losses of over 50 percent of the harvest have been reported (Raman, 1988). Nevertheless, weevils are an endemic pest which have evolved with potatoes, and farmers have learned to tolerate them. Traditional management practices, particularly long rotations and wide separation between fields planted with the crop, prevent the build-up of pest populations to catastrophic levels. Farmers try to sample for damage and harvest before losses become serious, although it can be difficult to monitor a large number of scattered fields planted in the same season. Farmers accept a certain amount of damage as inevitable. Within a traditional Andean household, potatoes have a variety of uses, each with a different threshold of tolerance for weevil damage (Werge, 1977).

- The largest and most choice tubers, with little or no damage, are selected for sale in the market or for trade.
- Smaller potatoes are selected as seed. Some insect damage is tolerated. After the harvest, tubers are exposed to the sun before they are moved into storage. The heat drives the larvae out of the tubers, and kills them (Yábar, 1986a).
- More damage is tolerated in tubers intended for home consumption, as affected portions can be cut out. Rural people say that weevils make potatoes "sweet."
- Small tubers and those which are so badly damaged that they would deteriorate rapidly can be processed using a variety of indigenous techniques of which the best known is freeze-drying into chuño (Yamamoto, in preparation).
- Very seriously damaged tubers are fed to livestock,
- In normal years, only a small residual is so badly damaged that it is discarded.

Chemical control

As potato production methods have become more intensive, farmers have come to rely increasingly on chemical control. Quality standards go up where the crop is produced primarily for the market, as urban consumers will not accept damaged tubers. The increased concentration of potato production in contiguous fields and the reduction in

fallow periods provide weevil populations with a regular source of food. Chemical insecticides have been increasingly used for the control of this pest in the Mantaro Valley since they were first introduced in the 1940's (Peralta and Javier, 1980).

Two major methods of chemical control are commonly used. The first is the application of granular insecticides (most commonly different formulations of *Carbofuran* sold under the brand names *Furadan* and *Curater*) to the soil at the time of planting. This systemic insecticide dissolves in the soil solution and is taken up by the plant, killing the insects as they feed for as long as the residual effect lasts. This practice has been heavily promoted by the chemical companies, and was followed by over 80 percent of the farmers interviewed in the Mantaro Valley during two successive seasons.

Nevertheless, soil applications at planting are not entirely effective. If the soil is too dry, the toxin will not dissolve and reach the pest. Adults continue to emerge for many weeks after the potato crop is planted, by which time the chemical will have lost its residual power.

On-farm research carried out in the late 1970's strongly suggested that it would be more effective to apply insecticides at the first weeding or at hilling, when a larger proportion of adult weevils are likely to be at a vulnerable stage, and to protect the tubers from larval feeding (Franco et al., 1981). With rare exceptions, however, this is not what farmers do.

One possible explanation is that insecticides applied at planting have the additional effect of controlling other pests in the soil, particularly cutworms and nematodes. Applications at planting are therefore correlated in the farmers' experience with increased yields four or five months later. Socioeconomic factors, particularly the organization of labor, are probably more important. Planting is a complex and labor-intensive operation. Seed tubers and fertilizers must be transported to the field and a labor force must be organized. The additional labor required to transport and apply insecticides at the time of planting is minimal, and is easier to organize than it would be later in the season.

A second common type of chemical control is to spray the plants with insecticides which the adults ingest as they feed on the leaves. Insecticides and fungicides are mixed to control other leaf-feeding insects, late blight (*Phythopthora infestans*), and other diseases.

Research on alternative control components at CIP

Entomologists at CIP have worked on several control components, including the screening of breeding lines for resistance, the identification of biological control mechanisms, and experiments on cultural practices (Raman, 1988). Fifty-six of the nearly 1,500 clones screened from the world potato collection exhibit low larval survival and low damage. A fungal pathogen (*Beauveria bassiana*) and two insect predators (*Harpalus sp.* and *Metius sp.*) have been identified in Peru, and their effectiveness as biological control agents is being investigated. It has been shown that adult weevils produce an aggregation pheromone, which has potential for both monitoring and control. The most effective cultural practice is to harvest early to avoid the build-up of the pest.

Field research in 1985-86

Characteristics of the sample

A sample of farmers in the Mantaro Valley was selected according to criteria based on the survey carried out in the previous season, and on previous research by the Social Science Department. The goal was to build upon what had been learned the previous year, and at the same time to minimize the logistical problems inherent in a multiple-visit survey. Three compact areas were chosen along the road which runs up the eastern side of the valley. Although all the zones include a range of altitudes up the sides of the valley and a broad range of types of farmers, the dominant characteristics of potato production in these zones are somewhat different (Appendix Figure 2).

The Pazos region[1] is located at the southern end of the relatively wide agricultural section of the valley of the Mantaro river which surrounds the city of Huancayo. "Traditional" varieties are widely grown at high altitudes, both for home consumption and for sale. Concepción is a prosperous town in the central area of the valley. The steeply rising slopes above it are cultivated intensively by small-scale commercial farmers who also grow a substantial proportion of their own food. They commonly grow crops in several plots at different altitudes, and sell their produce in regional markets. Agriculture in the flat lands surrounding Jauja, to the north, is dominated by commercially-oriented farmers, many of whom sell seed to coastal growers and ware potatoes directly to the Lima market. They use modern varieties and high levels of inputs, and achieve yields up to 60 t/ha.

Sample plots were distributed at different altitudes in all the provinces, although two-thirds of them were concentrated in the major band of potato production between 3,500 and 4,000 meters.

Nearly 50 percent of the farmers in the sample were cultivating a total of less than 2.5 hectares (Appendix Figure 3). About 60 percent of them had less than one hectare planted with potatoes, and nearly two-thirds of the individual plots where pest damage was monitored were less than half a hectare in size.

Varieties planted

Almost all of the farmers grew both traditional and "modern" varieties, produced by breeding programs over the past 30 years (Appendix Table 4). Forty-three percent of the sample fields were planted with a single variety, in all cases a modern one. A single variety accounted for between 75 and 99 percent of the seed planted in 9 percent of the cases, and for between 50 and 75 percent of the seed in 22 percent of the cases. Only about a quarter of the farmers followed the traditional pattern of intervarietal mixtures, where no one variety represented as much as half of the total plants. Farmers select varieties in terms of their taste, marketability, earliness, yield and many other factors, but resistance to insect attack was not reported as a significant criterion.

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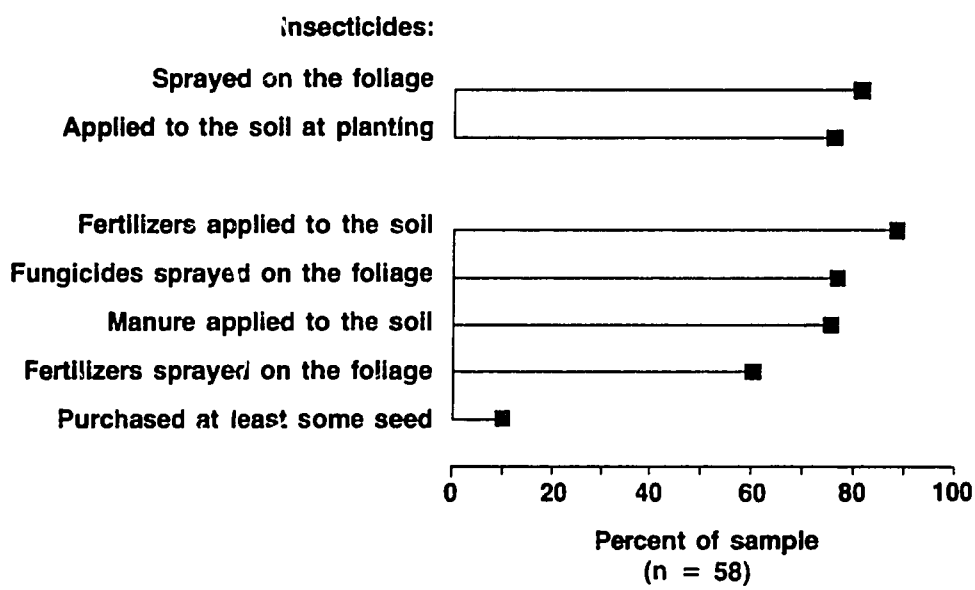
1. Farmers were selected from several districts near the town of Pazos, on both sides of the line between the Departments of Junin and Huancavelica.

Expenditure on inputs

The multiple-visit survey confirmed a major finding of the previous season --that insecticides were the most widely used purchased input into potato production, reported by over 90 percent of the farmers (Figure 6).

Figure 6. Mantaro Valley: Frequency of use of physical inputs in sample plots. 1986



Slightly more of them sprayed the foliage rather than applying it in the ground at the time of planting, but the great majority did both. Although most made use of manure from the farm, nearly 90 percent also applied chemical fertilizers. The season was somewhat rainier than the average, and nearly 80 percent sprayed fungicides, usually mixed in the same back-pack sprayers with the insecticides. Most agronomists both at CIP and in the national potato program, feel that foliar fertilizers have primarily cosmetic effects -- they make the plants look greener, but have little or no impact on yield. Nevertheless, over 60 percent of the farmers added fertilizers to their spray mix, at least on occasion.

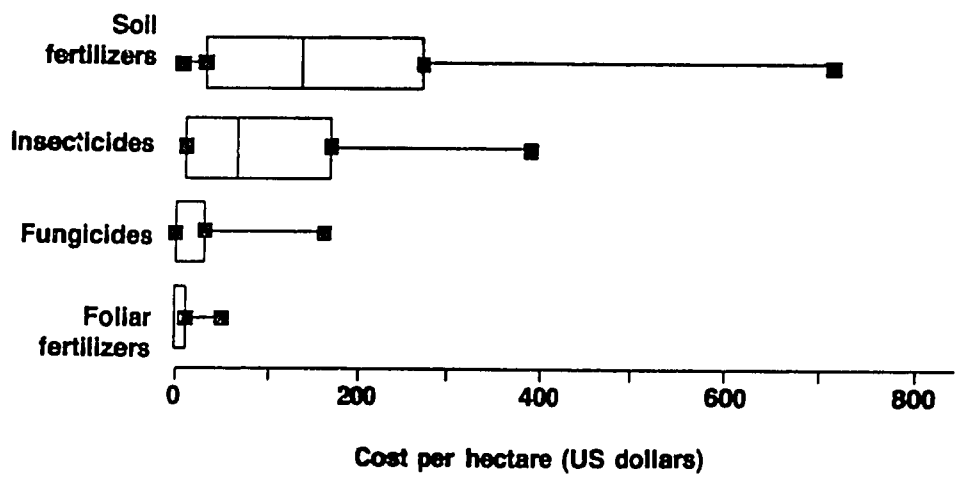
Throughout the highlands, farmers generally save a portion of their harvest and store it for replanting the next season. They purchase small amounts of seed in some years, and multiply it themselves. This allows them to counteract the degeneration of their crop from

the build-up of virus diseases and other causes (Prain, in preparation). Fifteen percent of the farmers in the sample purchased at least some seed in 1985.

The costs of the principal inputs were calculated by keeping track of the products the farmers used at each application. The prices actually paid varied greatly, depending on when and where products were purchased. To facilitate comparisons, a single set of retail prices was obtained from the outlets in the region most frequented by the people in the sample and then converted into US dollars.

The standardized expenditures per hectare varied widely among the farmers sampled -- it is meaningless to talk of "the farmers' practice" as if they all were doing the same thing (Figure 7).[2] Fertilizers applied to the soil were the single greatest cash cost, followed by insecticides. In all cases, expenditures on fungicides and foliar fertilizers were considerably less.

Figure 7. Mantaro Valley: Expenditures on inputs by sample farmers. 1985-86. (n=51)



Evaluation at Harvest

A total of 51 fields were sampled within a week before the harvest, most usually on the same day. In each case, we harvested and mixed three samples of three linear meters each.

2. These "box-and-whisker" diagrams, useful for the comparison of distributions, are constructed as follows. The vertical line inside each box is the median observation. Each box encloses the second and third quartiles, and the horizontal lines, or "whiskers" extend out to the minimum and maximum data points.

The plants were counted and their output weighed to estimate total yield. Those with various kinds of damage were separated out, counted, and weighed.

Yields by altitude and type of variety

The overall mean harvest was the equivalent of 22.1 t/ha (Appendix Figure 4). The highest median, about 23 t/ha, and the highest absolute observation, nearly 60 t/ha, were found in the zone between 3,501 and 3,750 meters. Most of the observations from 3,300 to 4,000 meters fell within the same general range. The sample of farmers above 4,000 meters was too small to draw conclusions from the much lower yields, although the cases consisted of small plots of native varieties, grown using traditional technology.

The median yield of the modern varieties was nearly 30 Tons per hectare, nearly twice that of the traditional types. The residual category of "mixtures" covers those fields where both kinds of varieties were grown in combination.

Weevil damage

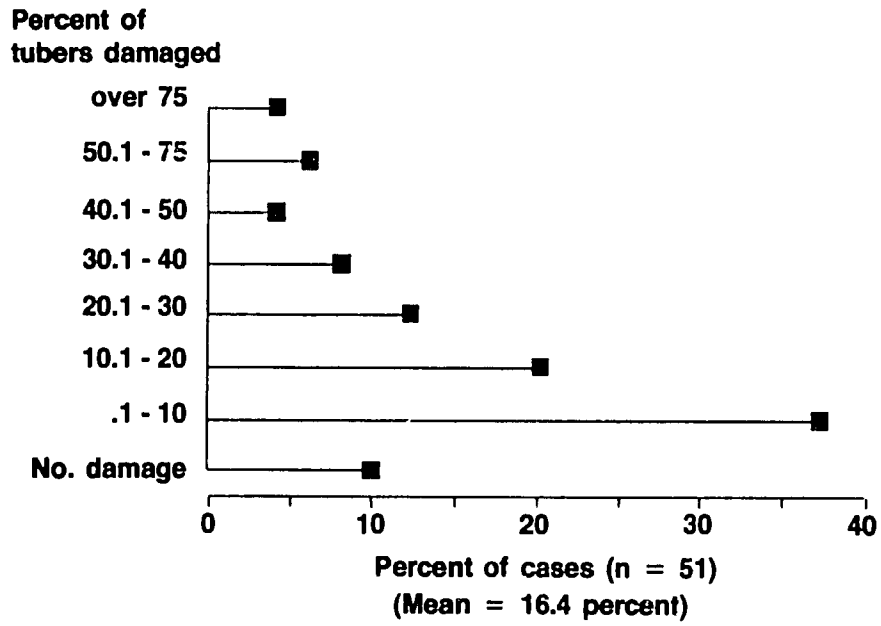
A mean of 16.4 percent of the tubers in all of the fields sampled showed at least some damage from Andean weevil. Damage ranged from zero to 70 percent (Figure 8). Damage from all other types of pests --primarily soil worms of the family *Noctuidae*, larvae of the beetle *Bothynus maimon* Erichson, and various unidentified fungal rots-- totaled only 4.8 percent, and ranged from zero to 42 percent.

Although only 10 percent of the samples were completely free of weevils, damage was relatively light. In 57 percent of the cases, 20 percent or less of the tubers were damaged. According to the farmers, this is approximately the level at which physical damage begins to be considered as a significant economic loss. As mentioned above, highland consumers have some tolerance for the pest, particularly for home consumption and for seed.

Damage by altitude and type of variety

The level of damage varied only slightly according to altitude zone or by type of variety (Figure 9). There was a tendency for damage to increase gradually in altitudes up to 4,000 meters, where it dropped off again. No major difference was observed between the level of attack on modern and traditional varieties.

Figure 8. Mantaro Valley: Distribution of damage by Andean weevil (*Premnotrypes spp.*) in farmers' fields at harvest. 1986



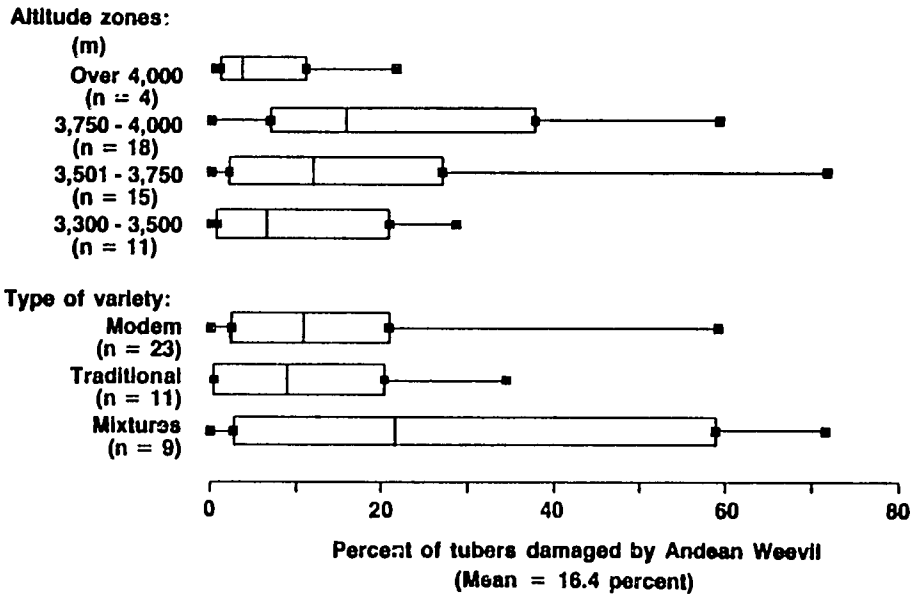
Fallow period and rotation pattern

It was hypothesized that one of the most important factors influencing the level of damage from the Andean weevil is the rotation pattern. Although the population dynamics of the insect under field conditions have not been adequately studied, it has been widely observed that the pest builds up rapidly in a field where potatoes are grown continuously (Yábar, 1986a).

In the sample, the correlation between fallow period and damage was obscured by the fact that fallow period was closely related to altitude (Appendix Figure 5). Without exception, all of the sample fields over 4,000 meters had previously been fallowed, whereas over 80 percent of those in the zone between 3,500 and 3,750 had not.

Although potato production in the areas sampled was quite intensive, the traditional Andean rotation pattern of potatoes followed by small grains and then fallow was found in nearly half of the cases (Appendix Figure 6). Potatoes had been replanted immediately after a grain, with no fallow, in 38 percent of the fields sampled. Continuous potato production was found in only about 10 percent of the cases. Nevertheless, over half of the farmers had grown potatoes in the same field within the previous four years. In 45 percent of the cases, potatoes were being grown in a contiguous field in the same year.

Figure 9. Mantaro Valley: Percent of tubers damaged by Andean weevil at harvest, by altitude zone and by type of variety. 1986



Harvest date

Other things being equal, the later the harvest, the more time weevil larvae have to find and attack the potatoes, and the more serious the damage will become. Harvest date was one of the cultural practices which was investigated in an on-farm experiment.[3] Two widely grown modern varieties, Yungay and Revolución, were planted. The plots were treated with a standardized schedule of pesticide applications similar to what many farmers in the area use. They were harvested at three different dates from the middle of April through the end of May. The damage at harvest was measured using exactly the same methods as the evaluations in the fields in the sample (Figure 10).

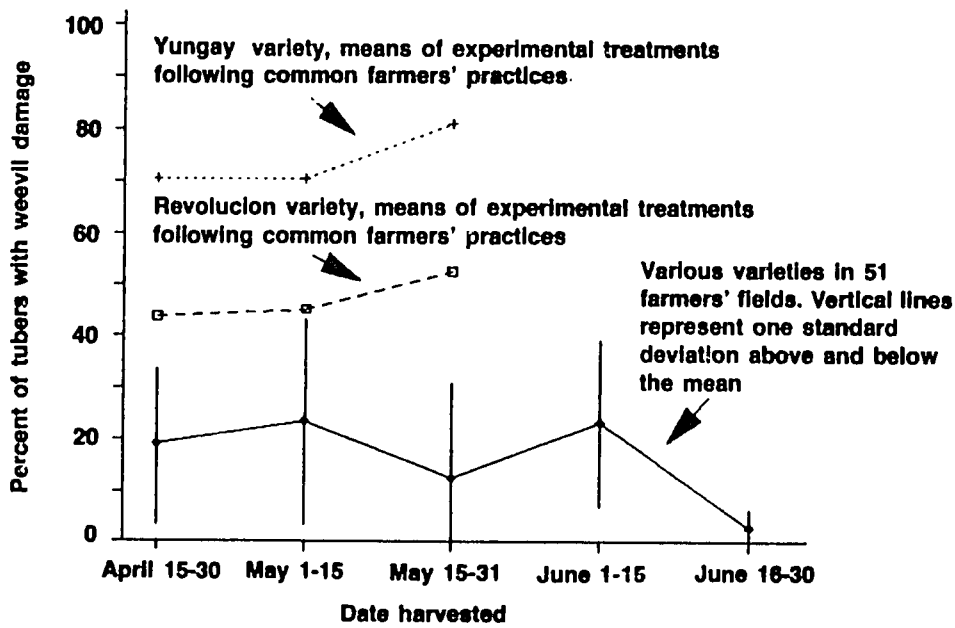
Damage to the Yungay variety went up from 70 to over 80 percent from the first to the last harvest. Revolución, an earlier-maturing variety, did somewhat better --damage went up from 43 to only 52 percent. The data taken in farmers' fields are not directly comparable. Nevertheless, they showed no tendency for damage to increase as the harvest was delayed. On the contrary, the percent of the tubers affected dropped down below seven percent at the end of June.

Two explanations for this can be offered. In the first place, the farmer's field used for the experiments on Andean weevil was chosen precisely because the level of initial infestation, and thus the total pest pressure, was high. The second is that farmers monitor

3. The experiment was run in the town of Concepción, under the direction of Biol. María Palacios, Ing. Jesús Alcazar, and Ing. Raul Salas of CIP's Department of Nematology and Entomology.

their fields and try to harvest them before weevil damage becomes serious. Infestation in the 1985-86 season was relatively light, and most people were able to stay ahead of the problem.

Figure 10. Mantaro Valley: Andean weevil damage at different harvest dates in an on-farm experiment and in farmers' fields. 1986



Several informants explained isolated cases of high damage as having taken place in plots distant from their homes which they were not able to watch carefully. In years with dry weather in April and May, weevil damage advances more rapidly than the farmers can organize themselves to harvest their multiple plots, and losses tend to increase rapidly. A multi-year monitoring program would be necessary to measure this phenomenon accurately.

Depth of tubers

Both the on-farm monitoring project and the experiment were designed to measure damage at the time of harvest from the potato tuber moth as well as from the Andean weevil. As the season was wetter than normal, essentially no damage from tuber moth larvae was found. The depth of the tubers below the soil surface is a critical factor in the management of that pest, because the larvae work their way down to the potatoes through cracks in the soil as the tubers mature. It was not expected that the depth of the tubers would have a major effect on damage by weevils.

The depth at which the tubers are found depends on three basic factors: the genetically controlled characteristics of the variety, the depth at which the seed is planted, and the height of the subsequent hilling. As expected, no significant differences were found between treatments at the five percent level (Appendix Figure 7). Some effect on weevil damage was found in a later experiment when the seed was planted 40 centimeters down, which is far deeper than normal farmers' practice (Raman, 1988).

In the on-farm monitoring, 10 plants in each field were chosen at random. The height of the hill to the bottom of the furrow was measured. Then the soil was carefully excavated down to the first five tubers encountered, and the distance to the top of the soil was measured. The average height of the hills at the time of harvest, after several months of erosion from the time of formation, was 23.9 centimeters. The average depth of the tubers below the soil surface was 6.2 centimeters. As expected, no correlation was found between either of these factors and the damage from Andean weevil.

Conclusions

The Andean weevil is an endemic pest which farmers have learned to live with. The economic damage and the costs of control fall within tolerable limits except in years with unusually severe conditions. Nevertheless, the insect is becoming an increasingly serious problem as production becomes intensified. Populations tend to build up when potatoes are concentrated into smaller areas, as fallow periods are reduced, and as the interval between potato crops in crop rotations becomes shorter.

Chemical control is almost universally used, although the type, rate, and cost of the products applied, varies over a wide range. Most farmers have been persuaded to apply granular insecticides at the time of planting, although there is good evidence that insecticides are far more effective if applied later in the season.

4. Potato Tuber Moth in Stores

The next stage of the research in the Mantaro Valley was to investigate insect pest problems of seed potatoes in storage.[1] The potato tuber moth, particularly the species *Phthorimaea operculella* (Zeller), is a major pest in most of the warmer areas of the world where the crop is grown (von Arx et al., 1987; von Arx et al., 1988). At CIP's experiment station in San Ramón, at 800 meters above sea level on the rainy eastern slope of the Peruvian Andes, damage to over 90 percent of the tubers stored for four months has been reported (Raman, Booth, and Palacios, 1987). Another species, *Symmetrischema plaesiosema* (Turner), is more aggressive and is rapidly becoming the more important pest in the major potato-producing areas of the highlands (Sánchez at al, 1986).

Both species feed on the foliage and sometimes the stems of the plants, but this only rarely causes significant reductions in yields. The larvae find their way down to the tubers and burrow into them. They cause damage at the time of harvest, but are primarily a problem later on, after the potatoes have been carried into the stores. The tolerance for infested tubers is low, as they have a foul odor and taste. Damage to the sprouts can make tubers unfit for use as seed. Although damage in storage under cool highland conditions is not normally catastrophic, farmers in the Mantaro Valley report that tuber moth is an increasingly serious problem.

Storage Practices

Peruvian farmers store potatoes for consumption, for later sale, and for seed. A series of studies carried out by CIP's Social Science Department have analyzed a broad range of traditional practices (Rhoades, et al., 1988). This study focused only on seed stores. Potatoes for seed are normally harvested between April and June, left out in the light for a few days to "green," sorted, and placed in stores until the next planting in October and November. In 1986, a combination of wet conditions and good market prices at the harvest, meant that 90 percent of the farmers in the sample bought some additional seed in July to store until planting time. They were interviewed about their practices in July and August, and their stores were monitored for damage in September and October.

Small-scale farmers store seed together with potatoes for consumption in whatever space is available: up above the rafters in the loft of the house or stable, or under the cover of the porch that faces the interior courtyard of most houses in the Andes. Larger, commercially-oriented farmers sort out a portion of their harvest, usually smaller tubers in reasonably good condition, to save as seed in storerooms, almost always located within the household compound (Appendix Figure 8).

1. The field research on storage pests was directed by Ing. Hugo Fano of the Social Science Department at CIP, with the close collaboration of Javier Carhuamaca and Raul Aldana, entomologists with the Peruvian national potato program.

Nearly 60 percent of the farmers surveyed, particularly household compounds located below 3,500 meters, kept their seed in special storerooms designated for that purpose. The others use a space in a room designated primarily for some other use: the porch, the stables, or the loft of the house.

How the tubers are placed in the store influences the microclimate for pests. The overwhelming majority of the farmers piled up the tubers in heaps, thus creating dark, moist conditions. Nearly 20 percent of them left the tubers in the same sacks in which they were brought from the field: this suggests that they were not carefully selected. Only a small minority carefully spread the tubers out on the floor, which is the recommended practice.

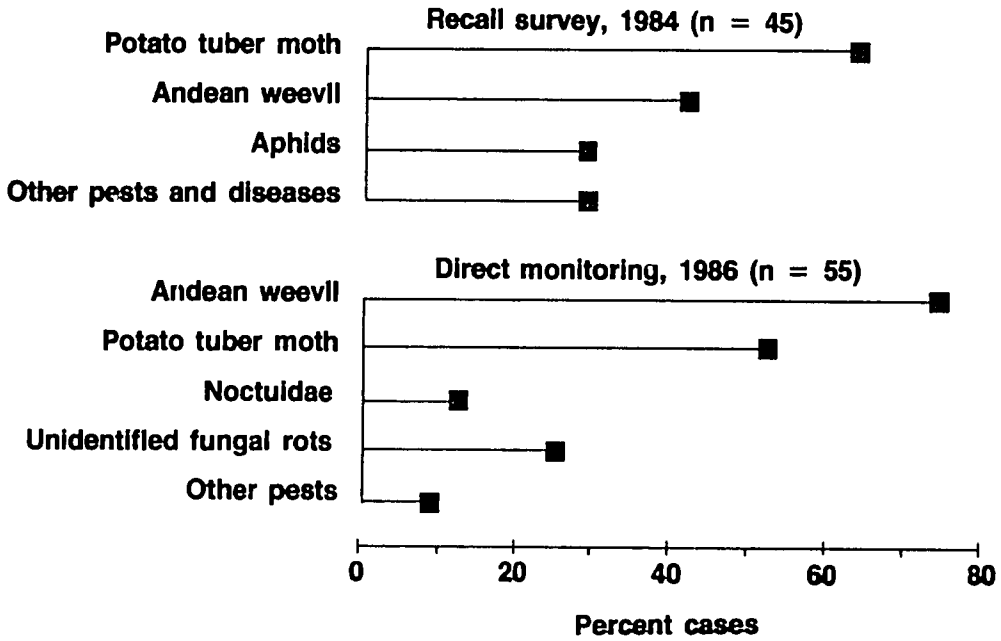
Research at CIP and in many national research institutes has shown that storage in indirect, diffused light is the most effective way to maintain the quality of seed tubers. The skin turns green and bitter, but the growth of sprouts is slowed and the seed stays more vigorous. The Peruvian program has worked for a number of years to encourage farmers in the Mantaro Valley and elsewhere to adapt the storage facilities and materials which they have available to this basic principle (Rhoades et al., 1988). Nevertheless, nearly two-thirds of the farmers in the sample stored their seed in the dark, in part because they did not separate them from ware potatoes. About 30 percent stored their seed in a place where some light could enter, through a window or from under the roof, but did not make any effort to ensure that all the tubers were evenly exposed. Only three farmers in direct contact with the extension department had effectively adopted the technology.

Storage pests

In the first survey carried out in the 1984-85 growing season, 45 farmers in the Mantaro Valley were asked to recall their pest problems in their seed stores in 1984 (Figure 11). Over 60 percent mentioned the potato tuber moth. The next most important was the Andean weevil, which are also carried into stores. The damage of the latter pest is not regarded as seriously, because partial infestation does not make the tubers inedible or unusable as seed, and also because traditional control methods are reasonably effective. Aphids can attack the sprouts of the tubers at certain times in the storage cycle, which may be an important pathway for the spread of virus diseases (Booth, Shaw, and Harmsworth, 1981). Although over 20 percent of the farmers reported having seen them, none regarded aphids as significant problems. No other important insect pests were identified. The study did not try to identify or assess the damage caused by fungal diseases.

Pests were monitored directly in 55 farmers' seed stores during September and October, 1986. This group was a sub-sample of the survey on field management practices carried out during the previous season, with the addition of 10 more farmers. All were located in the same three provinces. Andean weevil was found in over 70 percent of the stores, and tuber moth in about 50 percent. Nevertheless, all of the farmers regarded the latter as the more damaging to the seed. Worms of the genus *Noctuidae* and unidentified fungal rots were less widespread.

Figure 11. Mantaro Valley: Relative frequency of storage pests, in recall survey, 1984 and in direct monitoring, 1986

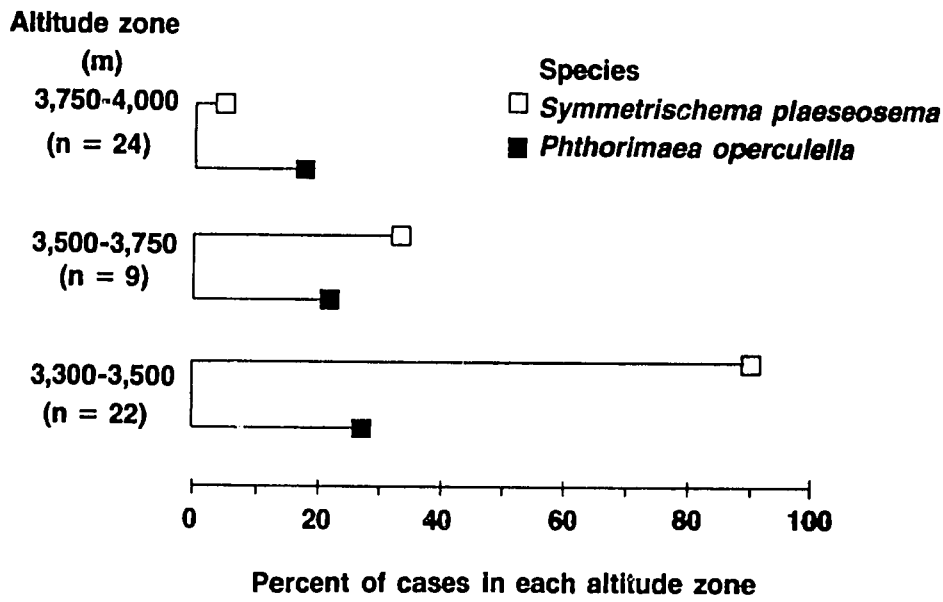


S. plaesiosema was found in over 90 percent of the stores in the zone below 3,500 meters, but its frequency dropped off sharply at higher elevations (Figure 12). The farmers reported that this was a new pest, the importance of which had been increasing rapidly in the previous few years. It is particularly serious for the farmers who live in the larger communities at lower altitudes. *P. operculella* was found in approximately 20 percent of the stores in all of the zones.

Pest Control Practices

Management practices can be an effective method for controlling pests in seed stores. The space should be carefully cleaned of old potatoes, sacks and other sources of infestation, and only clean, carefully selected tubers should be placed in storage. Forty-seven percent of the farmers, particularly those at higher elevations with cooler conditions where *S. plaesiosema* is not a problem, did not use any special control practices. Insecticides, applied both to the storage space and to the tubers themselves, were used by 27 percent of farmers. Of the eight products they used, only Decis is recommended for use in stores (Appendix Table 5).

Figure 12. Mantaro Valley: Distribution of two species of potato tuber moth in farmers' stores by altitude zone. 1986



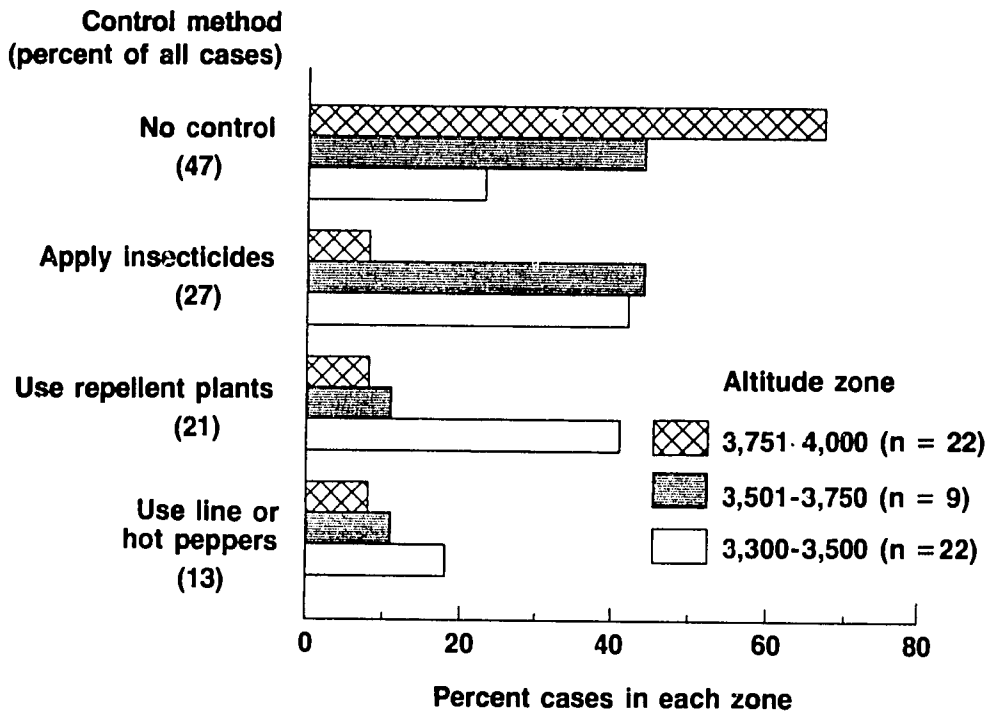
Repellant plants, both *Eucalyptus* and *Muña* (*Minthostachys sp.*) were used by nearly a quarter of the farmers. Research at CIP has shown that both of these plants can reduce pest attack, by acting both as physical barriers and as repellants. To be most effective, the leaves must be dried and ground, and the resulting powder spread evenly over the storage heap (Raman, 1988). The traditional practice is to place fresh branches of the plants in the stores as repellants, which is not nearly as effective. Agricultural lime or hot peppers were used as barriers in a few cases.

Damage

Potato tuber moth is a serious problem in the Mantaro Valley only in unusually dry, warm years. Rainfall in 1986 was above average, so the farmers did not expect to see major damage. Evaluations were made in September and October, between 60 and 90 days after the seed tubers were put into storage (Figure 14).

No damage whatever was found in about a third of the stores. In approximately half of them, up to 12.5 percent of the tubers showed at most one exit hole from a PTM larva. In 12 percent of the cases, up to 25 percent af the potatoes were attacked. In four cases, more than 25 percent of the store was affected.

Figure 13. Mantaro Valley: Distribution of insect control measures in farmers' seed stores by altitude zone. 1986

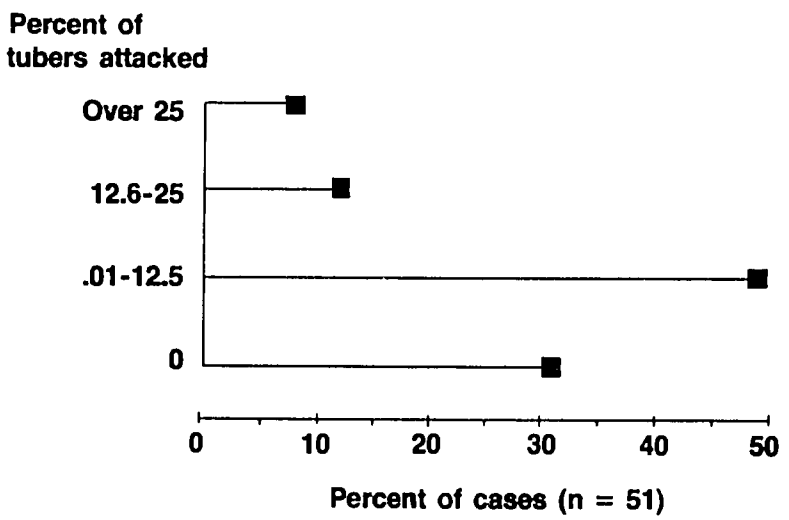


In five of the cases, the 10 most damaged tubers were cut in half and sorted into four groups according to the scale of visual damage developed by Raman and Booth (Raman and Booth, 1984). The farmers were then asked which of the piles would make acceptable seed. All agreed that the tubers classified as #1 and #2, with relatively minor damage, could be planted, and that those in class #4 were clearly unusable. Although one of the farmers thought that those in class #3 might sprout if the eyes were not damaged directly, all said that they would cull such seed out before planting. Combining the two worst classes, we can conclude 38 percent of the damaged tubers would have been rejected as unfit for use as seed. Further research in years when tuber moth attack is more serious will be required to specify the damage threshold more precisely.

Results of an experiment

The next year, in 1987, an experiment was run in farmers' stores to evaluate the effectiveness of different methods of control. The tubers were placed in storage in July. Four stores were treated as replicates, and a common farmers' practice which did not include applications of insecticides or repellant plants was used as the check. As one treatment, a layer of ground, dried eucalyptus leaves five centimeters deep was spread evenly over the stored heap. As a second, a .05 percent powder of the pyrethroid insecticide Deltametrine (Decis) was dusted evenly over each layer of potatoes as the tubers were placed in the store. The previous two practices were combined as a third treatment.

Figure 14. Mantaro Valley: Damage from potato tuber moth in seed stores of sample farmers. 1986



Environmental conditions were once again not favorable for the growth of populations of the insect, so levels of damage were low in all cases (Appendix Table 6). At the first evaluation, 40 days after the tubers were placed in storage, all three treatments showed significantly less damage than the check at the five percent level according to the Duncan multiple range test. At the second evaluation, after 88 days of storage, the insecticide treatment was significantly different from eucalyptus used alone. These results are inconclusive, as damage levels in the check were not high enough to justify any expenditure on control. Other studies, however, have shown that repellant plants can be a cost-effective alternative to insecticides under many circumstances (Raman, Booth, and

Palácios, 1987). Further on-farm tests are being carried out in cooperation with national researchers, both in Peru and in other parts of the world.

Conclusions

The potato tuber moth is regarded by farmers in the Mantaro Valley as a relatively new and increasingly serious pest. They say that their current practices do not provide adequate control in dry, warm years. There is anecdotal evidence that the problem is associated with the increased flow of seed into the central highlands from the warmer coastal valleys. The species *S. pluesiosema* is more important than *P. opercullela*, particularly at elevations below 3,500 meters, where many farmers live and store their seed. As researchers, we were unlucky that infestation was relatively light in both the 1986 and 1987 storage seasons, as we were not able to conclusively evaluate the effectiveness of either the farmers' practices or CIP's experimental control measures. A modest, on-going program of interviews with small samples of farmers, monitoring of damage in their stores, and simple experiments would clarify the frequency of the problem over a period of years, and would help to identify the best alternatives within the framework of integrated control.

5. The Leaf Miner Fly in Cañete: A Pesticide Treadmill

The problem of the leaf miner fly (*Liriomyza huidobrensis* Blanchard) in the Cañete Valley is a valuable case study of the vulnerability of intensive potato production to new pests, particularly when the crop is grown outside of its traditional agroclimatic range.

Expansion of potatoes into a new agroclimatic zone

Cañete is one of the irrigated valleys along the desert coast of central Peru. Historically, large estates specialized in the intensive production of first sugar cane and then cotton for export. The cold waters of the Humboldt current create cool, foggy conditions in the winter months from May through September, when potatoes can be grown. The crop became important commercially starting in the early 1950's, with the rapid growth of the urban market in Lima, 150 kilometers to the north. The harvest from October through December comes just when supplies from the major production regions in the highlands are at their lowest, and prices are at a seasonal high.

The production of potatoes and other food crops increased rapidly in the 1960's and 1970's when the large estates were converted to cooperatives through an agrarian reform. The area in production then decreased dramatically in the 1980's (Figure 15). One of the major factors behind this decline was the steady increase in the costs of production, particularly for the control of the leaf miner fly. Farmers substituted other crops with lower costs of production and/or more stable market prices, particularly sweet potatoes and maize (Achata, Fano et al., in press).

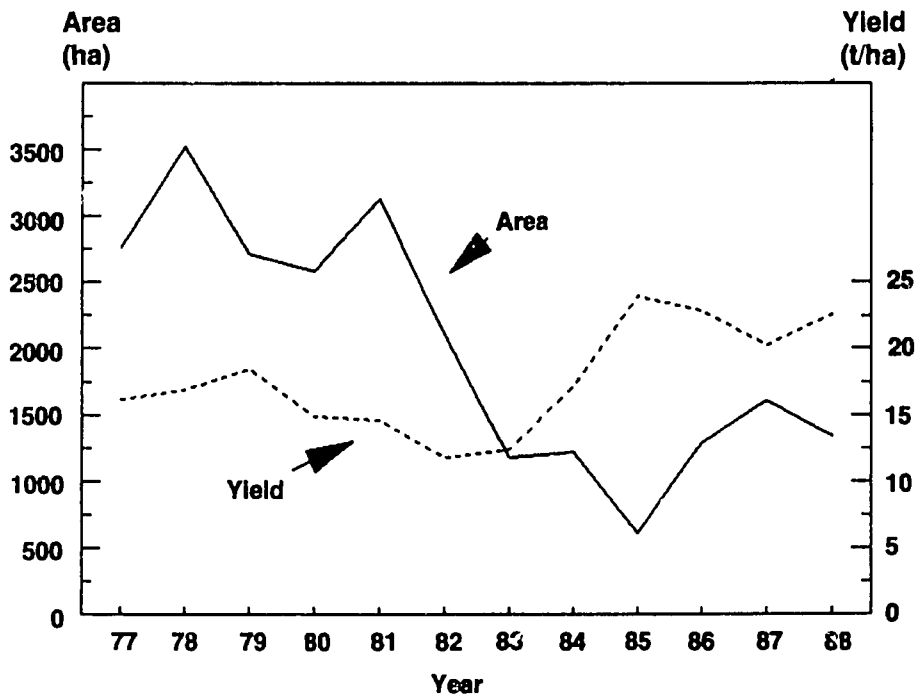
Uncontrollable growth of the pest

L. huidobrensis was collected in Cañete in the 1940's, but it was not an important pest of any crop at that time (Wille, 1952). Insecticides were first introduced into the valley after the Second World War for use on cotton. They were applied to potatoes to control a species of potato tuber moth (*Scrobipalpula absoluta* (Meyrick)) which damaged the plant primarily as a stem borer (Herrera, 1963; Campos, 1979).

The leaf miner fly is a pest that attacks the leaves of the potato plant, which can reduce yield. Attempts to kill all the insects are counter-productive, as the massive use of insecticides affects the natural enemies of the pest more than the pest itself, and actually increases the problem. Cañete is an isolated valley in the desert -- the widespread spraying of virtually all green plants with insecticides throughout the year puts insect populations under very heavy selection pressure. The local populations of the fly have developed

resistance to all classes of insecticides, forcing farmers to progressively increase the dosage of ever more expensive chemicals (Delgado, 1980). The only other potato pest of any significance in the valley is late blight. Nevertheless, in bad years, pest control can account for 40 to over 50 percent of the cash costs of production. This is much higher than in the highlands, where the figure fluctuates between five and fifteen percent.

Figure 15. Cañete Valley: Area in potato production and average yield. 1977-88



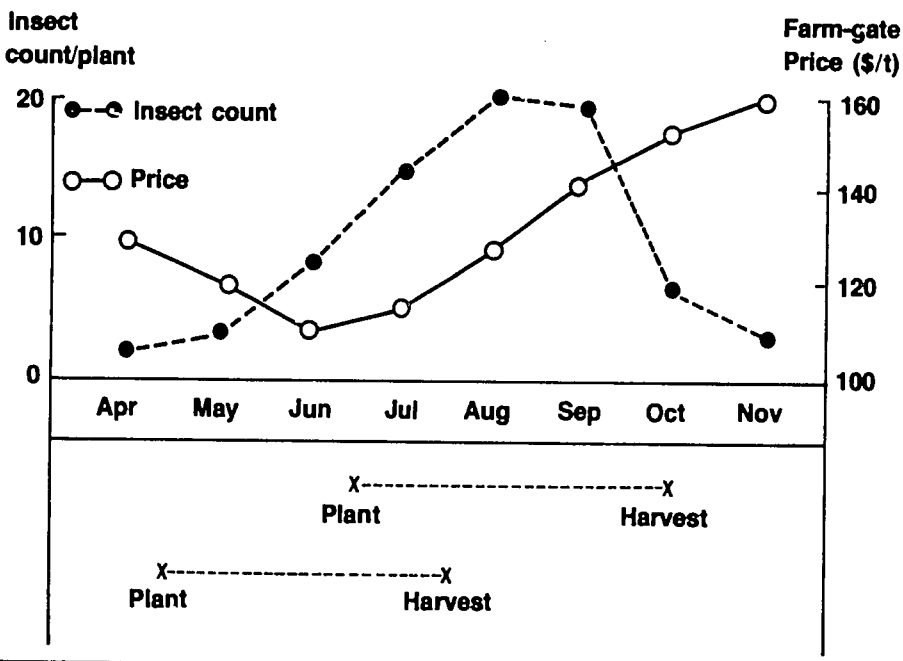
Source: Peru, Ministry of Agriculture

Adults of the leaf miner fly lay their eggs in the leaves, where the larvae hatch. They mine through the leaves, reducing photosynthetic capacity and eventually killing them. The damage typically starts near the base of a plant and works its way up. The impact of the loss of effective leaf area on final yields depends on the age of the plants, the variety, and other factors.

In their pest management decisions, farmers must juggle unpredictable levels of insect attack and yield reduction, a range of types of pesticides with very different costs, and unpredictable prices at the time of harvest (Figure 16).

The population of the insect is controlled by its natural enemies in the hot summer months, builds up rapidly from May through August, and then drops off again. Potato prices in the Lima market tend to reach their annual low at the end of June, the major harvest period in the highlands. They rise gradually through the rest of the year, as stocks are depleted. The precise shape of both of these curves is highly variable from one year to another.

Figure 16. Cañete Valley, Peru: Expected patterns of leaf miner fly infestation and farm-gate potato prices



If they can find seed, farmers can plant potatoes in Cañete as early as the end of April. This early crop will avoid the worst period of pest attack, but market prices are likely to be low at harvest. Most farmers plant in June and July. Their fields are exposed to high populations of the fly, so they spray repeatedly with combinations of expensive products in the hope that high prices at harvest will compensate their costs. By the mid 1980's the Cañete Valley became the site of a pesticide bonanza. The streets in the small towns were lined with stores selling pesticides, and chemical companies found willing collaborators to test novel, high-cost products like insect growth regulators.

Earlier experience with integrated pest management

Ironically, the Cañete Valley is famous among entomologists as the site of one of the earliest major successes in the history of integrated pest management. A complex of cotton pests developed resistance to the organochloride insecticides in use in the mid-1950's, which led to a complete breakdown of control in 1956 (Boza, 1972).

The farmers, most of whom operated large estates, organized themselves to implement an integrated control package. It included the planting of short-season varieties, the establishment of fixed planting and harvest dates, the prohibition of ratoon cropping, the burning of stubble, the use of arsenic insecticides which have minimum impact on natural enemies, and the rearing and release of biological control organisms. The program saved cotton production in the region, and its essential elements have been maintained for over 30 years.

There have been repeated attempts to apply a similar approach to potato pest management, with very limited success (Yábar, 1986b). Heterogeneous farmers growing a perishable crop for a volatile market have simply not had the short-term incentives to accept regulations, even if they would help to reduce pest populations in the valley as a whole.

An interdisciplinary study

There has been a long history of research by several institutions on the leaf miner fly in the Cañete Valley: a private experiment station set up by estate owners (Campos, 1979), the national potato program (Delgado, 1980), and the PRACIPA network (Yábar, 1986c). Over half of the published results have concentrated exclusively on methods of chemical control, and only 13 percent have worked on integrated methods. The same basic recommendation --plant tolerant varieties early-- has been promoted for over 20 years (Yábar, 1986b).

The current project was one part of a series of studies at CIP which included entomological studies of the population dynamics of the pest and physiological studies of the response of different varieties of potatoes to attack at different stages of plant growth. The socioeconomic research component started with an informal diagnostic survey in 1984. In 1985, a sample of 28 farmers was chosen for a detailed multiple-visit survey of their pest management practices. This work was designed to provide a context for experiments being carried out concurrently both in Cañete and at CIP's headquarters in La Molina, near Lima. We collected data on pest management and other input costs, and tested a simple visual scale as a rapid field method for estimating damage (Yábar, 1986c). A simplified survey and monitoring program was continued for a second year in 1986 with 10 farmers. Other aspects of the larger project have been reported separately (Midmore, 1986).

Characteristics of the sample

There are two major types of potato farmers in the valley, the beneficiaries of the land reform and independent farmers. Immediately after the reform, the ex-estates were reorganized as parastatal cooperatives. In response to government policy favoring food crops, potatoes were grown on a large scale using mechanized technology. During the period of the study, between 1984 and 1986, the cooperatives were divided among the members into individual parcels. The beneficiaries had no other assets, and were dependent on the government bank for production credit.

The independent farmers are a heterogeneous group, ranging from small holders along the margins of the valley, to intensive vegetable producers of Japanese descent, to a few contract operators who rent land to produce the crop on a relatively large scale. Smaller farmers with limited resources may use animals rather than tractors, and spend less on inputs. Nevertheless, the same basic production system is practiced by all the farmers in the valley --there is much less difference between operations than in the highlands. The sample of 28 farmers chosen in 1985 was designed to provide a cross section.

Size of farms

The largest number had between 5 and 20 hectares under cultivation, and less than 5 hectares in potatoes (Appendix Figure 9).

Varieties grown

Seed was obtained from highlands, both from the Mantaro Valley and from Huasahuasi on the eastern slopes of the Andes where the harvest is earlier. In 1984, two varieties each accounted for a third of the total area --the relatively long-season Tomasa Condemayta and the earlier Revolución (Appendix Figure 10).

Many farmers in the preliminary survey told us that Tomasa Condemayta was less sensitive to the leaf miner fly. Physiological research carried on in cooperation with this project suggests that this belief is based on a misinterpretation by farmers of how the varieties respond to massive damage to their leaves. Tomasa Condemayta has relatively tall plants with an upright growth habit. Its leaves regenerate rapidly after an attack. Revolución has a low, spreading growth habit and appears to suffer from damage very dramatically. Nevertheless, this variety is earlier bulking, and so moves its energy supplies more quickly into the tubers. The difference in yield at the time of harvest is small or nonexistent (Midmore, 1986).

To reduce the sources of variability in the survey, we decided to concentrate on these two varieties in our more detailed survey the next year. In fact, relatively few farmers planted Revolución in 1985, so the other short-season varieties Ticahuasi and Mariva were substituted. Over 95 percent of the area in the valley was planted with these four varieties.

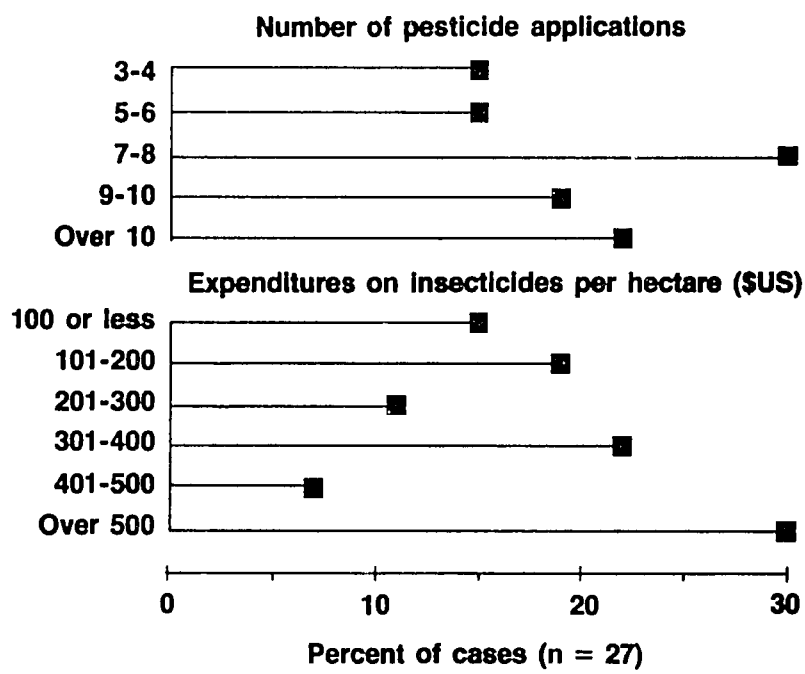
Other crops

Potatoes are a cool season crop, grown in rotation with other crops, most commonly sweet potatoes, maize, various vegetables, and cotton.

Pest management strategies and costs

The leaf miner fly is a short-lived, prolific insect, and populations can build up very quickly. About a third of the farmers in the sample applied granular insecticides to the soil at the time of planting, but spraying was the most important control method. Most farmers watch the number of adult flies in the field, and spray with insecticides as soon as they see the numbers begin to build up. In 1985, the number of applications, including soil treatments ranged from three to twelve (Figure 17) and the average number was eight. The largest number of farmers in the sample sprayed seven or eight times.

Figure 17. Cañete Valley: Distribution of cases by number of pesticide applications and by expenditures on insecticides per hectare. 1985

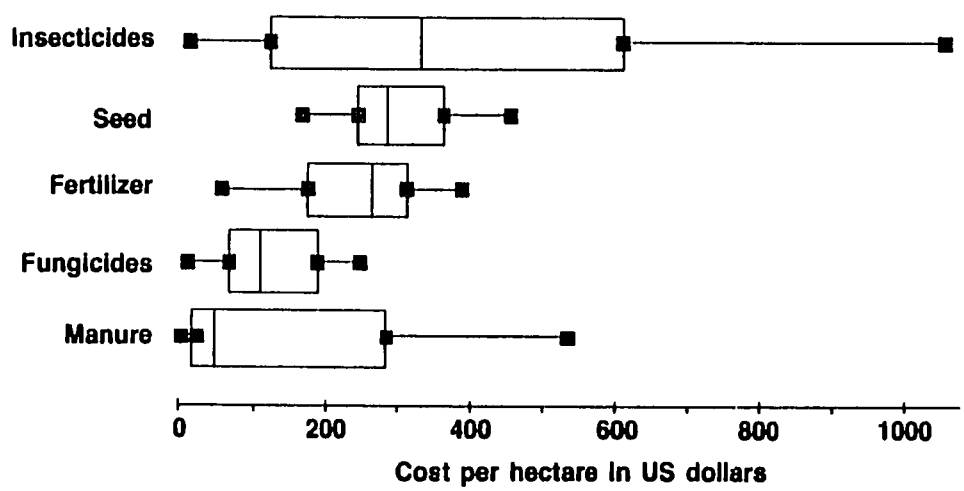


Cost of products used

The cost of applications was calculated by detailing all of the products used in every spray application, calculating the rate per hectare, and multiplying by a standard price in dollars derived from the retail prices in the valley at the beginning of the growing season. Inflationary pressure on the costs of inputs was thus excluded from the analysis. The prices of potatoes closely tracked the prices of pesticides over the period studied, although the very rapid inflation greatly complicated decision-making by farmers (Appendix Figure 11).

Total expenditure on insecticides ranged from the equivalent of US$ 9.50 to over US$ 1,000 per hectare. Insecticides were the highest input cost in the sample, followed by seed, fertilizer, fungicides, and manure, which is purchased from intensive cattle and poultry operations (Figure 18).

Figure 18. Cañete Valley: Expenditures on selected inputs, sample of 27 farmers. 1985



The single most important factor influencing expenditure on pesticides was the type of products used. Appendix Table 7 compares four typical spray mixes. In the cheapest, the mineral insecticide *Lead Arsenate* is mixed with the fungicide Polyram-Combi, as protection against possible infestation by late blight, and with molasses which attracts the insects. All of the other examples combine two different insecticides with different types of action: Perfecthion is an organo-phosphate, Polytrin 200 is an artificial Pyrethroid, and Trigard is an insect growth regulator, which inhibits the normal development of the insects. The farmers had had so much experience in the past with products that lost their effectiveness as the insects developed resistance that they were very susceptible to the claims of salesmen for newer, ever more expensive products.

Effect of planting dates

One of the basic hypotheses of the study was that farmers who plant early can avoid the period of high pest populations. This idea was only weakly supported by the data (Figure 19). Sixty percent of the farmers who planted before May 15 spent less than the equivalent of US$ 200 per hectare on insecticides. About half of those who planted after June 15 spent between US$ 200 and US$ 400. Nevertheless, a significant proportion of the sample spent much more, irrespective of when they planted. There are two explanations for this. First, potatoes are grown in the valley in a patchwork of fields planted at different times. Some early plantings were sprayed very heavily to prevent their becoming a source of infestation for nearby fields. The other reason is that many farmers simply become convinced that frequent treatments are the only way to insure a crop.

The average yield obtained by the farmers in the sample was 21.1 t/ha, and the range was 16 to 34 tons. There was no clear relationship between yield and either planting date or total expenditure on pesticides --other factors weighed at least as heavily. Farm-gate prices varied depending on short-term market factors, but tended to rise between September and December.

Field monitoring of damage

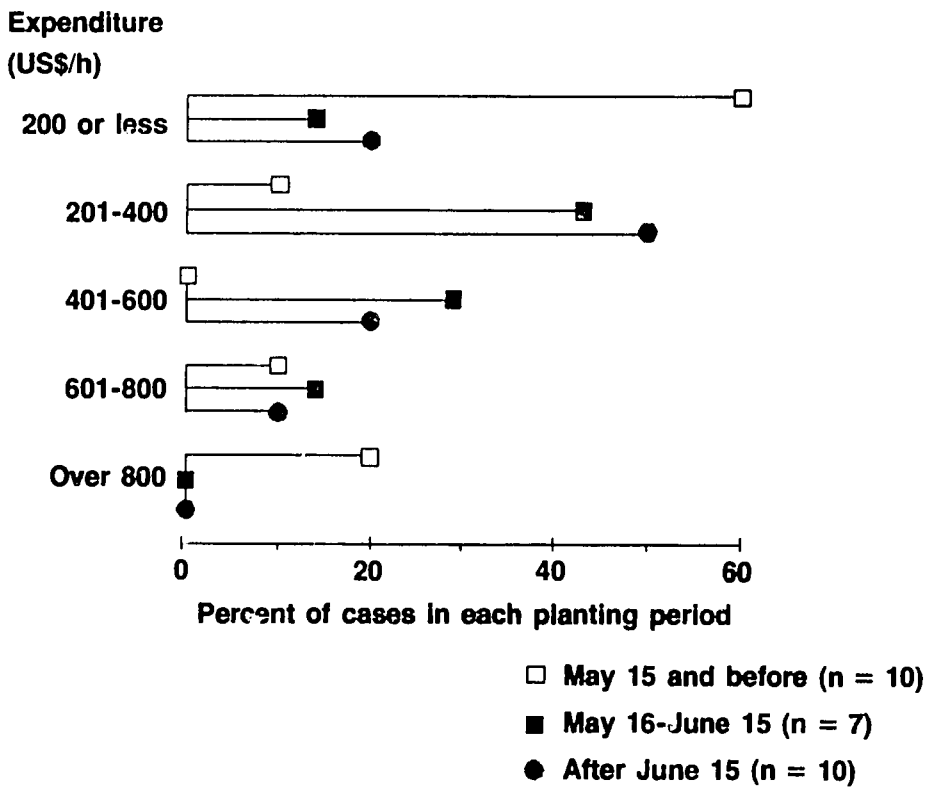
Field monitoring is a critical component of any program designed to help farmers reduce applications of pesticides. The most common method is to count the number of adults per plant of a sample. The results are sensitive to the time of day, wind conditions, how recently nearby fields have been sprayed, and other factors which are difficult to standardize. The number of larvae in a sample of leaves is a more reliable measure of potential damage, but accurate results require a laboratory technique. An entomologist from the Peruvian national potato program, working in collaboration with CIP, developed the simple visual scale of damage from one to five (Yábar, 1986c):

- No damage.
- Necrosis in the lower third of the plant; small mines in the middle third.
- Necrosis has progressed to the middle third of the plant; more than half of the leaves in the lower third are necrotic; small mines in the upper third.
- Bottom and middle thirds have become predominantly necrotic; whitened mines in third upper third are intermixed with small to medium necrotic areas.
- Lower thirds are now essentially defoliated; the upper third is largely necrotic.

The scale proved to be a valuable tool for the rough monitoring of the spread of the pest, as it provides a quick and easy basis for comparing the degree of damage found in different fields. Its applicability as a tool for setting action thresholds for pest management is questionable. First of all, it measures the cumulative effect of the pest on the plants, not the pest population at the moment the assessment is made. The scale depends on

subjective judgement, so it is difficult to compare ratings made by different people unless they work together very closely. Finally, it is possible to confuse the necrosis caused by the leaf miner fly with the effects of other factors.

Figure 19. Cañete Valley: Distribution of expenditures on insecticides by planting date. 1985



Conclusions

The potato production systems in the Cañete Valley have proved very sensitive to rising costs of inputs resulting from a classic "pesticide treadmill." To date, it has proved impossible to organize an integrated pest management system similar to the successful program for cotton pests developed in the same area a generation ago. Cotton is an industrial crop with an assured market and price, grown under the regulation of well-established institutions. Potatoes are a perishable crop, sold to a volatile market with many alternative sources of supply. The short-term interests of individual farmers, rather than the benefit of the community as a whole, have dominated pest management decisions.

6. General Conclusions

The costs of pesticides, and their effects on human health and on the environment are increasingly serious problems in Peru, as in the rest of the world. Potatoes are vulnerable to many insects and diseases both in the field and in storage. Under the pressures of growing a high-value crop with high costs of production, potato farmers have strong incentives to apply pesticides to avoid catastrophic losses. Advertising by multinational firms and the advice of salesmen and local merchants have been far more effective at providing timely (although sometimes erroneous) information than the government's research and extension services. Certain products and application practices have therefore widely adopted, even though there is good evidence that these are neither the most effective nor the most economical technologies which could be used.

Chemical control is not a sustainable pest management strategy in either entomological or economic terms. There is an urgent need for the development of more effective and economical technologies that will avoid the familiar problems of the "pesticide treadmill." Success depends on better knowledge both of the pests themselves and of the conditions under which farmers make pest management decisions.

Integrated pest management (IPM) only becomes a reality when various components are taken up by farmers and combined and adapted according to their own conditions. Technologies like improved varieties can be adopted by individual farmers independently of what their neighbors are doing, but many pest management systems are only effective if members of a community agree to coordinate their practices.

Interdisciplinary research and extension are required to provide farmers with better components and to help adapt them to local circumstances. On-farm research --surveys, on-farm monitoring, and on-farm experiments-- have important roles to play. This exploratory study has brought these elements together to learn about farmers' management of three important insect pests, and to explore methods for incorporating the users' perspective into entomological research. The specific conclusions are tentative, but some general lessons can be drawn.

Farmers' perceptions of pests are very useful sources of knowledge, that can be used as a first step to guide the design of monitoring and experimental programs. Potato production systems include a number of elements with both direct and indirect effects on pest populations and damage. Many of the mechanisms are not fully understood by the farmers themselves. Both the severity of pest attack and farmers' management practices are highly variable, both over short distances and from one year to another. No single "farmers' practice" used as a treatment in an experiment can provide adequate assessment of the advantages or shortcomings of a particular component technology.

The successful development of integrated pest management technologies requires an integrated program of research with an interdisciplinary perspective. Samples need not be large and the research need not be elaborate, but regular, systematic interaction with farmers is essential. Few national agricultural research systems (NARS) have adequate personnel or budget to field multidisciplinary teams to work on every important research problem. Social scientists can play important roles by helping to identify representative

farmers and key constraints within production systems, and by providing simple methods for data collection and analysis. Entomologists and extensionists should be trained to routinely gather information from farmers to complement data from on-farm monitoring and experiments. Resources should be allocated for transport and other costs, on a modest scale if that is all that is possible, but on a regular and continuing basis. Linkages with extension should be strengthened.

Appendices

Table A1. Pesticides used by Peruvian potato farmers

Brand name	Chemical name	No. of farmers reporting use
Insecticides (46)		
Furadan	Carbofuran	51
Aldrin	Aldrin	43
Tamaron	Methamidophos	34
Aldrex-2 Folidol-2	Aldrin + Parathion	31
Parathion	Parathion	31
Curater	Carbofuran	30
Perfekthion	Dimethoate	29
Folidol	Parathion	28
Evisect	Thiocyclam	25
Trigard	Cyromazine	20
Aldrex-2	Aldrin	19
Vydate	Oxamyl	16
Lead Arsenate	Lead Arsenate	
Ripcord	Cypermethrin	10
Metasystox	Oxydemeton	8
Decis	Decamethrin	8
Temik	Aldicarb	6
Padan	Cartap	6
Polytrin-200	Cypermethrin	5
Monitor	Metamidophos	5
Baytroid	Cyfluthrin	4
Brestan	Triphenyltin	4
BHC	BHC	3
Volaton	Baythion	3
Ambush	Permethrin	2
Azodrin	Monocrotophos	2
Endrin	Endrin	2
Enditrion	Endrin + Parathion	2
Pounce	Permethrin	2
Alsystin	Triflumuron	1
Arrivo	Cypermethrin	1
Baygon	Propoxur	1
Belmark	Fenvalerate	1
Curacron	Profenofos	1
Cymbush	Cypermethrin	1
DDT	DDT	1
Dimethoate	Dimethoate	1
Dipterexy	Trichlorfon	1
Ekatin	Thiometon	1
Gamexan	BHC	1
Gusathion	Azinphos-ethyl	1
Hexano	BHC	1
Malathion	Malathion	1
Monofos	Metamidophos	1
Sherpa	Permethrin	1

Brand name	Chemical name	No. of farmers reporting use
Fungicides (18)		
Dithane	Mancozeb	38
Ridomil	Metalaxyl	37
Antracol	Propineb	33
Polyram-combi	Metiram	30
Tecto-60	Thiabendazole	10
Agallol	MEMC	7
Manzate	Maneb	6
Cupravit	Copper	5
Rhizoctol	Methylarsinic	5
Vitavax	Carboxin	5
Tri-miltox	Macozeb + copper	4
Homai	Thiophanate	3
Pentachlor	PCNB	3
Fitoraz	Antracol + Cymoxanil	3
Benlate	Benomyl	2
Cobox	Copper	2
Bravo 500	Chlorothalonil	1
Cercobin-M	Thiophanate	1

Source: Figures in all tables are results of interviews with 241 farmers, 1984-1986

Table A2. Local names for insect pests reported by 85 farmers in Cuzco and the Mantaro Valley, 1984-85

Andean Weevil (*Premnotrypes spp.*)
Common Spanish name: Gorgojo de los Andes

Local names for larvae:

Cuzco	No.	Mantaro Valley	No.
Papakuru	43	Shacra	13
Ichukuru	2	Papakuru	11
Itakuru	2	Gusanera	2
Manko	1	Gusano arroz	1
Allpakuru	1	Kulokuro	1
Tuksa	1	Sajrakuro	1
Champa mayukuru	1	Acshokuro	1
		Barrenador	1

Local names for adults:

Cuzco	No.	Mantaro Valley	No.
Papakuru maman	13	Gorgojo	3
Uti-uti	3	Cuzco	2
Palla-pallakuru	2	Ticshincunca	1
Cuchi-cuchi	2	Capachokuro	1
Naboskuru	1	Capakuro	1
Jusipachakuru	1	Atakuro	1
Tanapusca	1	Zorro-zorro	1
Uchakuru	1		
Jachu-jachu	1		
Laqhakuru	1		
Tankallo	1		

Potato Tuber Moth (*Phthorimea operculella* and *Symmetrischema plaeseoma*)
Common Spanish name: Polilla

Local names:

Cuzco	No.	Mantaro Valley	No.
Waytu	10	Polilla	2
Ichukuru	3	Calakuro	1
Ranchakuru	2	Barrenador	1
Thuta	2	Pintado	1
Uña aschu	1		
Taladro	1		
Wira wira kuru	1		
Nutu silhui	1		
Barreno	1		
Tala	1		
Seca-seca	1		

(Cont.)

Table A2 (cont.)

Flea Beetle (*Epitrix spp.*)
Common Spanish name: Pulguilla

Local names for larvae:

Cuzco	No.	Mantaro Valley	No.
Ichukuru	8	Estaquilla	1
Kirkiska or Kirki	5	Ichukuro	1
Sarna	1		
Paspa	1		
Rancha	1		

Local names for adults:

Cuzco	No.	Mantaro Valley	No.
Piki-piki	34	Pike-pike	13
Chuspi-chuspi	3	Pulgón	12
Papakuru	3	Cuchi-cuchi	4
Ithakuru	1	Pulguilla or pulguita	3
Cernidor	1	Jurochuspe	1
Pulguilla	1	Chuspe	1
		Ninakuro	1
		Gorgojo	1

Soil worms (of the genus *Noctuidae*)
Common Spanish name: Gusanos de tierra

Local names:

Cuzco	No.	Mantaro Valley	No.
Silhui	46	Utushkuru or Utush	42
Utushkuru	4	Ajanllay	1
Mancco	3	Shiuri	1
Waytu	1	Papakuro	1

Stem borers (*Stenoptycha sp.*)
Common Spanish name: Barrenadores del tallo

Local names

Cuzco	No.	Mantaro Valley	No.
Waytu	18	Barrenador	13
Barreno	5	Broca	2
Silhui	4	Polilla	2
Ichukuru	4	Rancha	2
Ranchakuru	3	Cañero	1
Papakuru	3	Tumba papa	1
Taladro	2	Utush	1
Thutakuru	1	Tunshukuru	1
Tornillo	1	Joshcca	1
Aschu	1		
Illac maman	1		

(Cont.)

Table A2 (cont.)

Blister beetles (*Epicauta spp.* and *Meloe spp.*)
Common Spanish name: Escarabajo negro de la hoja

Local names

Cuzco	No.	Mantaro Valley	No.
Karhua	34	Señas or Shiñas	16
Uchu-uchu	3	Yanakata	7
Tiktikuru	2	Shenao or Shina	6
Reipacuchi	2	Tipishkunka	3
Onchakmama	1	Pichinkunka	3
Yanachuspi	1	Huanca	2
Llama-llama	1	Shinaolo	1
Yanakuru	1	Yanahuanca	1
Uti-uti	1	Yanaayo	1
Mutu-mula	1	Hannash	1
Paya-paya	1	Añasco	1
		Manto negro	1
		Aguaskuro	1
		Aviskuro	1
		Linancolí	1
		Tipiskuro	1
		Padrekuro	1
		Pascashu	1
		Ticshinco	1

Leaf beetles (*Diabrotica spp.*)
Common Spanish name: Escarabajo verde

Local names:

Cuzco	No.	Mantaro Valley	No.
Lorito	7	Ulo-ulo or Ulu-ulu	2
Ccomerkuru	3	Escarabajo	1
Chuspi	2	Gorgojo verde	1
Jusipacha	2	Sangaño	1
Chiqchikuru	1	Verdechuspi	1
Lakakuru	1		
Papa kuru	1		
Illa huachackuru	1		
Illac maman	1		
Ccomer karhua	1		

(Cont.)

Table A2 (cont.)

Leaf cutters (*Acordulecera sp.*)
Common Spanish name: Gusano esquelitizador de la hoja

Local names:

Cuzco	No.	Mantaro Valley	No.
Illa	10		
Hach'uy	17		
Ccomer silhui	10		
Ccomerkuru	1		

Aphids (*Myzus persicae* and others)
Common Spanish name: Pulgón

Local names:

Cuzco	No.	Mantaro Valley	No.
Ita	3	Piojera	1
Illac maman	3	Chia verde	1
Usa-usa	3		
Chuspi	2		
Piojillo	2		

Table A3. Life cycle of the Andean Weevil (*Premnotrypes suturicallus*); average duration of the major growth stages

Growth stage	Average duration (days)	Range (days)	C.V. (%)
Eggs	32.7	19 - 42	6.7
Larval stages:			
I	11.4	4 - 21	17.3
II	9.3	6 - 18	20.6
III	12.3	9 - 18	15.5
IV	14.2	11 - 17	13.17
Total as larvae	45.8	42 - 51	6.7
Pre-pupae	42.7	31 - 56	21.8
Pupae	54.4	44 - 70	17.2
Adults over-wintering	115.0	85 - 142	20.0
Adults before oviposition	8.8	2 - 14	21.5
Mature adults	105.8	14 - 153	17.3
Total	406.6		

Source: P. Alcalá C. y J. Alcázar S. 1976. "Biología y comportamiento de *Premnotrypes suturicallus* Kuschel (Col.: *Curculionidade*)." Revista Perunana de Entomología. 19: 49-52.

Table A4. Mantaro Valley; varieties reported by sample farmers, 1985-86

Variety	No. of farmers reporting	% of sample (n=69)
Twelve improved varieties from breeding programs:		
Yungay	17	25
Revolución	15	22
Huancayo	7	10
Mi Perú	3	4
Bella	2	3
Caranora	2	3
Cuzco	2	3
Mariva	2	3
Renacimiento	2	3
Tomasa Condemayta	2	3
Antarqui	1	1
Tumi	1	1
Twelve traditional varieties:		
Tarmeña	5	7
Camotillo	4	6
Huayro	3	4
Muruhuayro	3	4
Regalo	3	4
Amaya Blanca	2	3
Larga	2	3
Shiri	2	3
Amarilla	1	1
Chata	1	1
Huamantanga	1	1
Negra	1	1
Mixtures (no dominant variety)	9	13

Table A5. Mantaro Valley: Pesticides used in stores by 51 farmers, 1986

Pesticide	No. of Users
Decis	3
Folidol	3
Aldrin	2
Aldrex	1
Baygon	1
Volaton	1
Malathion	1
Tamaron	1

Table A6. Mantaro Valley: Results of experiment in four farmers' stores, 1986

Treatment	After 40 days Mean	.05% Sig.[1]	After 88 days Mean	.05% Sig[1]
Check (farmers' current practice, with no applications)	7.53	a	11.29	a
Eucalyptus: a 5 cm. layer of ground, dried leaves	3.67	b	6.28	b
Decis: .05% powder, dusted uniformly over tubers	1.89	b	2.99	c
Decis and eucalytptus	2.05	b	3.07	

1. Different letters indicate that the means of the treatments are significantly different at the 5 percent level, according to Duncan's multiple range test.

Table A7. Cañete Valley: cost of four typical spray mixes, 1985

Products	Type	Application rate	US$/Unit	US$/ha
Mix I.				
Lead Arsenate	Mineral insecticide	3 kg	3.50/kg	10.50
Polyram-combi	Fungicide	1.5 kg.	9.18/kg	13.75
Molasses	Attractant	1.5 gal.	2.00/gal	3.00
Total				27.25
Mix II.				
Evisect	Contact insecticide	350 g	59.70/kg	20.90
Perfeckthion	Organo-phosphate insecticide	525 cc	6.26/l	3.28
Polyram-combi	Fungicide	900 g	9.18/kg	8.26
Citowett	Spreader/sticker	175 cc	$7.14/l	1.25
Total				32.70
Mix III.				
Polytrin 200	Pyrethroid insecicide	200 cc	79.59/l	15.71
Perfeckthion	Organo-phosphate insecticide	400 cc	6.26/l	2.50
Ridomil	Fungicide	1.5 kg	24.85/kg	37.28
Citowett	Speader/sticker	175 cc	7.14/l	1.25
Total				56.75
Mix IV.				
Trigard	Insect growth regulator	140 g	.88/g	123.20
Evisect	Contact insecticide	350 cc	59.71/kg	20.90
Polyram-combi	Fungicide	1 k	9.18/k	19.18
Citowett	Speader/sticker	175 cc	7.14/l	1.25
Total				164.53

Figure A1. Mantaro Valley and Cuzco: Characteristics of sample farmers in diagnostic survey, 1984-85

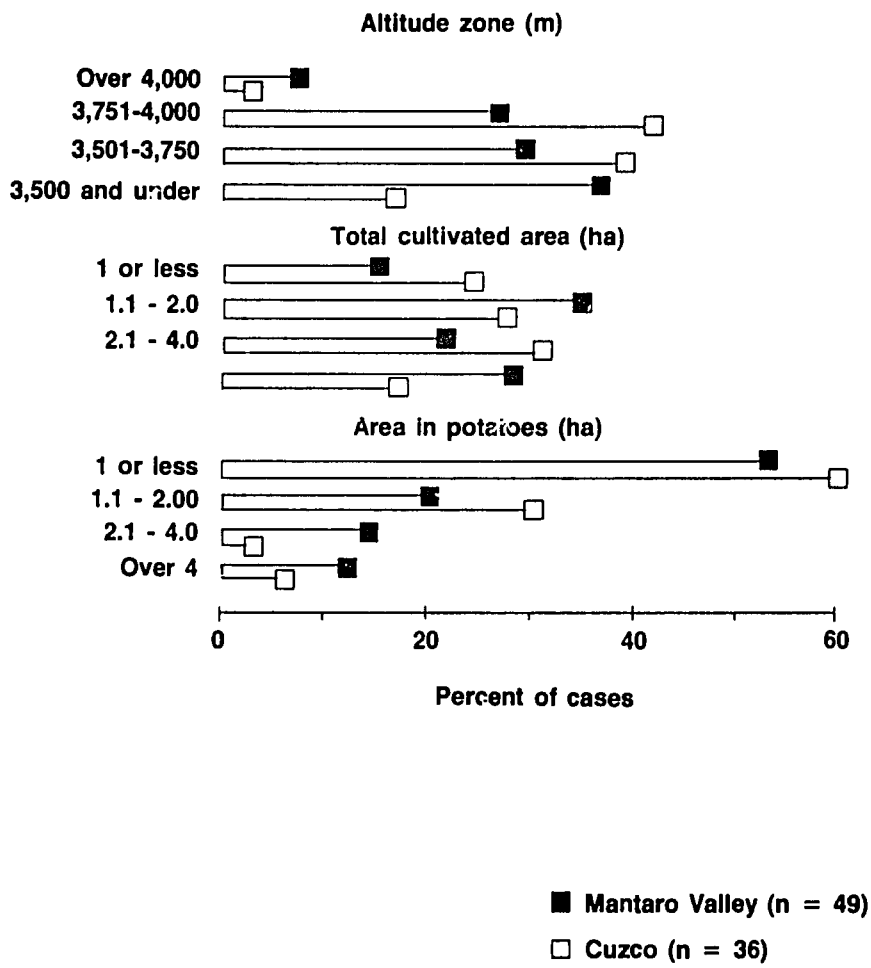


Figure A2. Mantaro Valley: Distribution of farmers' fields monitores by province and altitude zone, 1985-86

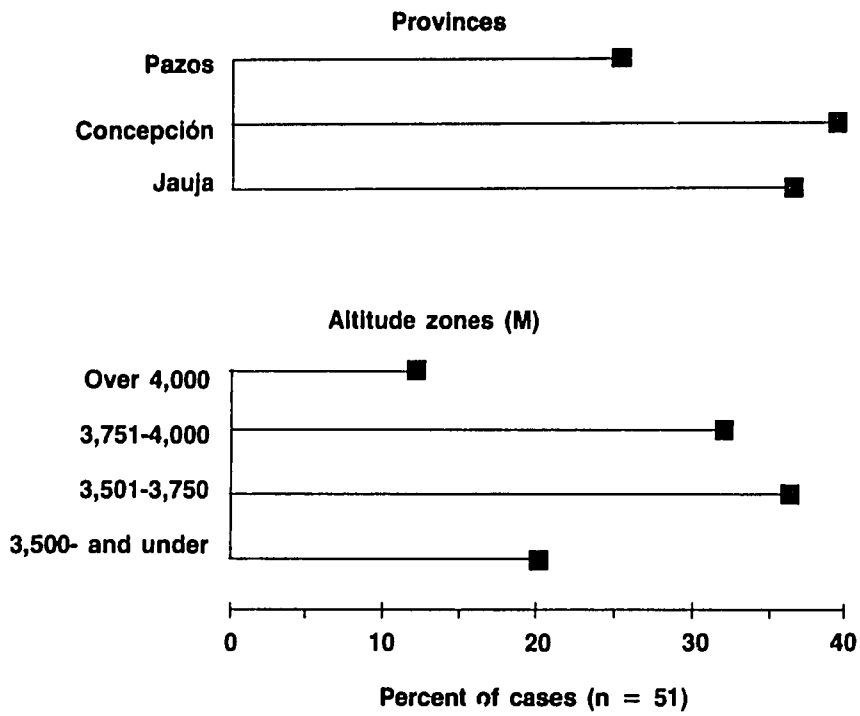


Figure A3. Mantaro Valley: Area of sample plots, total area in potatoes, and total area in field crops, 1985-86

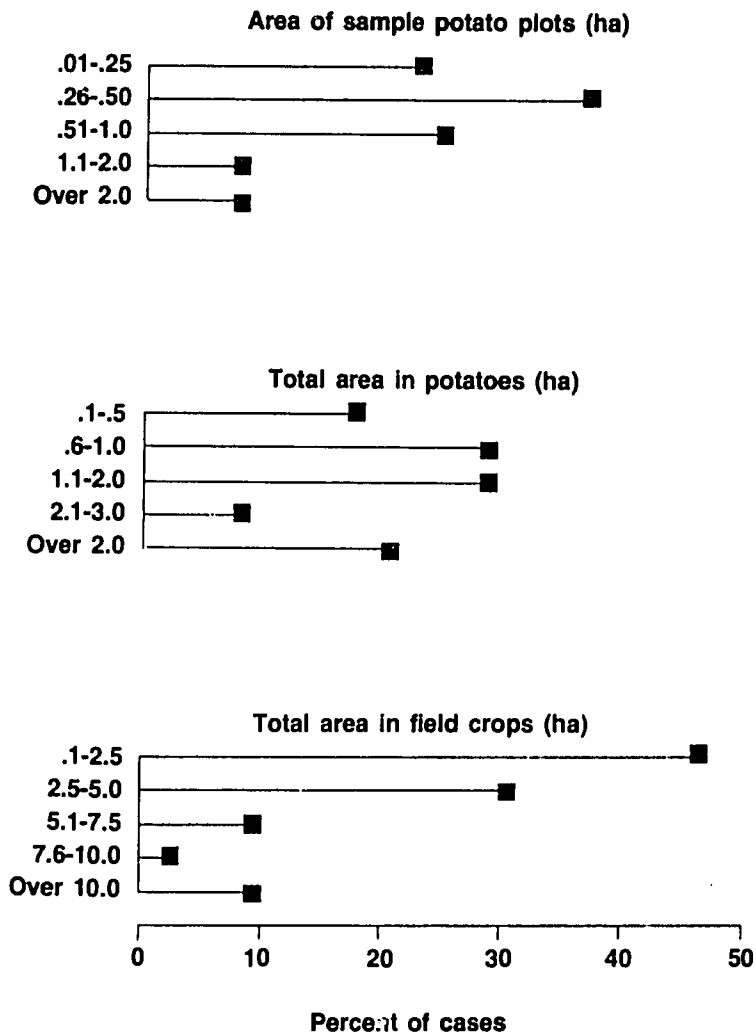


Figure A4. Mantaro Valley: Potato yields in farmers' fields by altitude zone and by type of variety, 1986

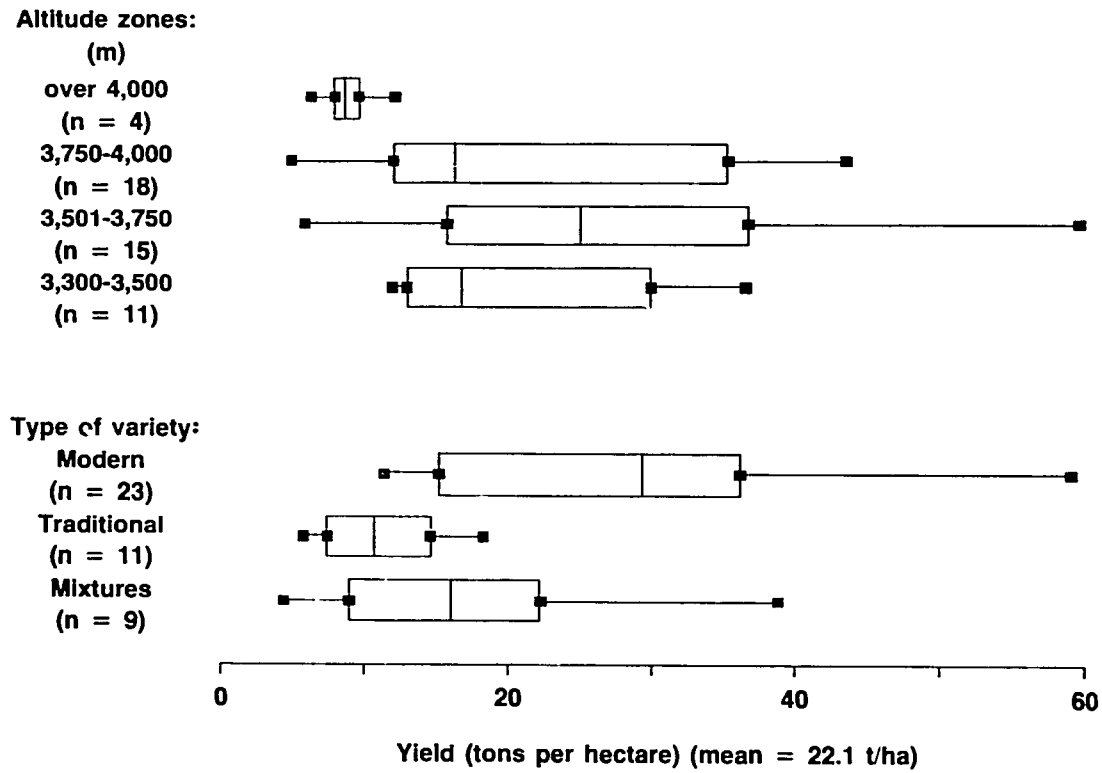


Figure A5. Mantaro Valley: Length of fallow period previous to current potato crop on farmers' fields by altitude zone, 1986

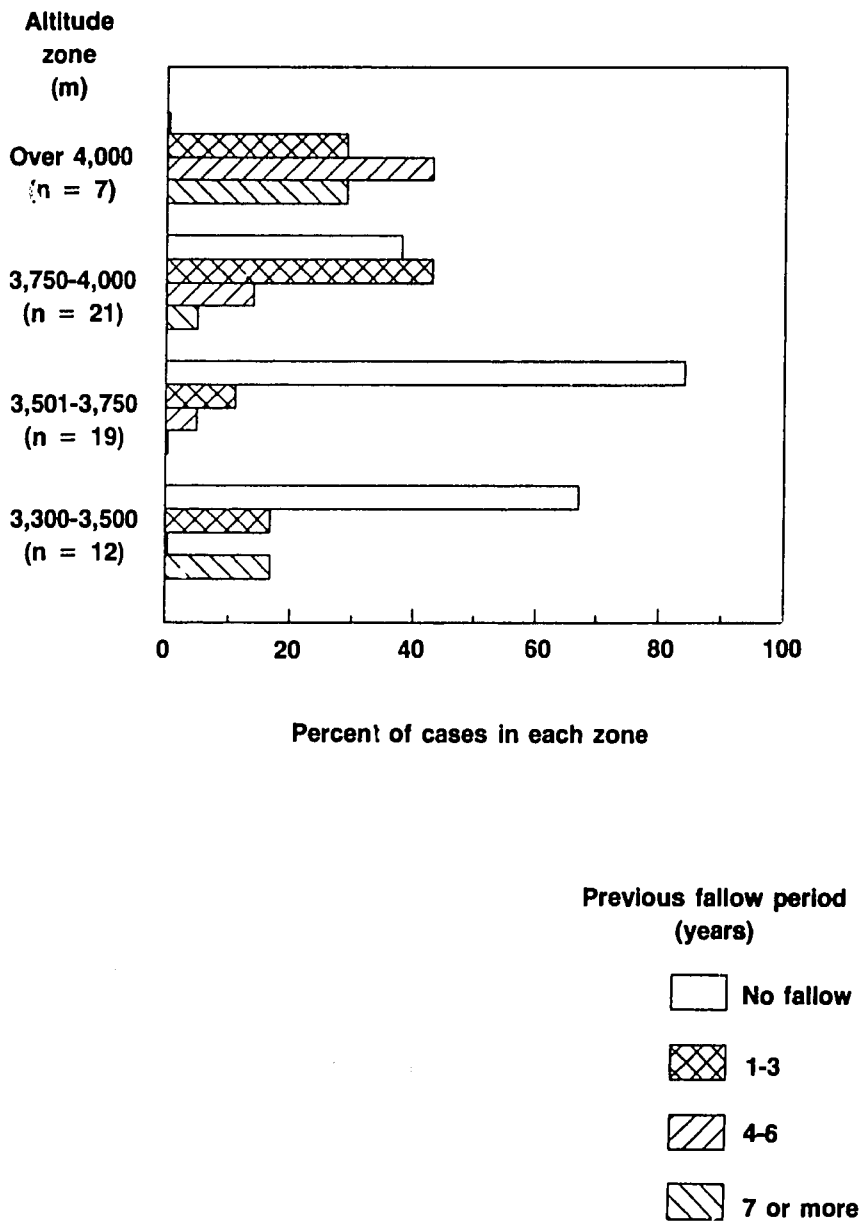


Figure A6. Mantaro Valley: Rotation patterns in sample plots, 1986

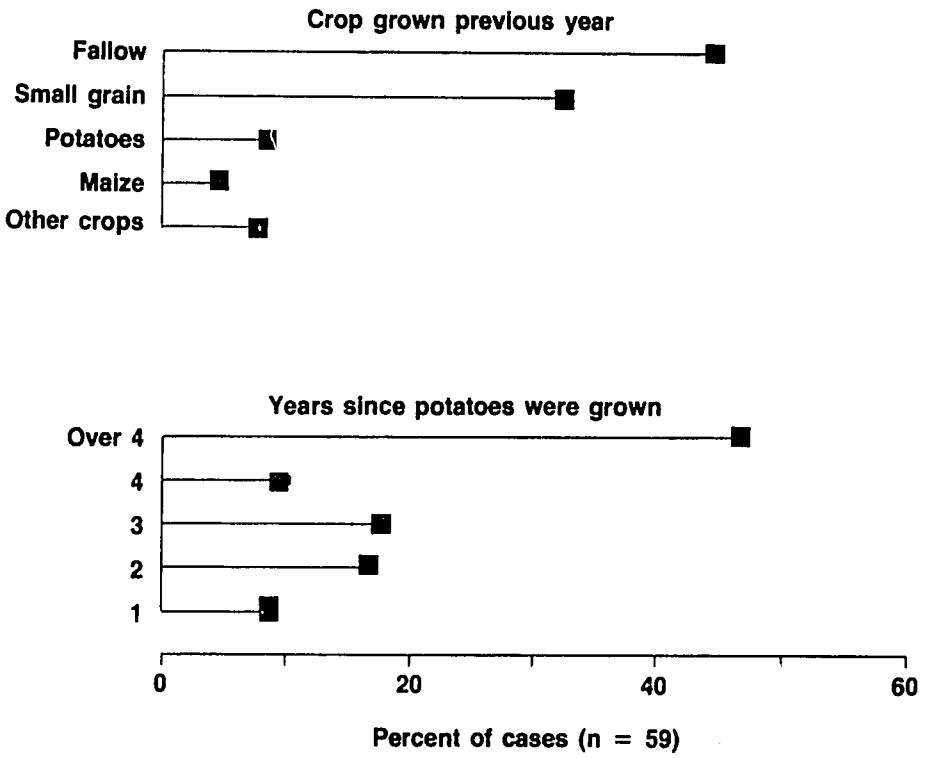


Figure A7. Effect of planting depth and hilling height on damage by Andean Weevil at harvest: Results of an on-farm experiment in the Mantaro Valley, 1986

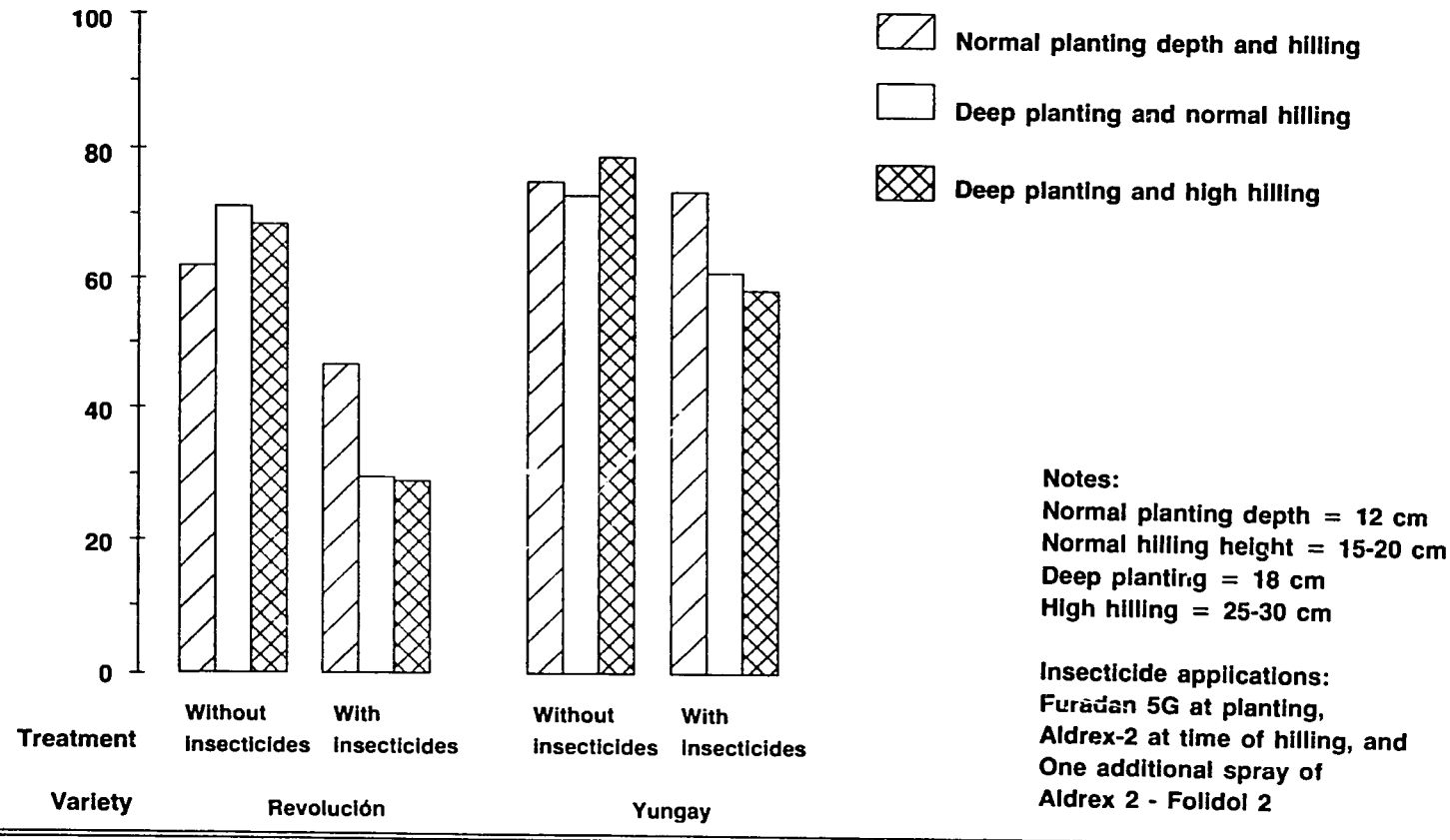


Figure A8. Mantaro Valley: Characteristics of farmers' seed storage systems in 1986

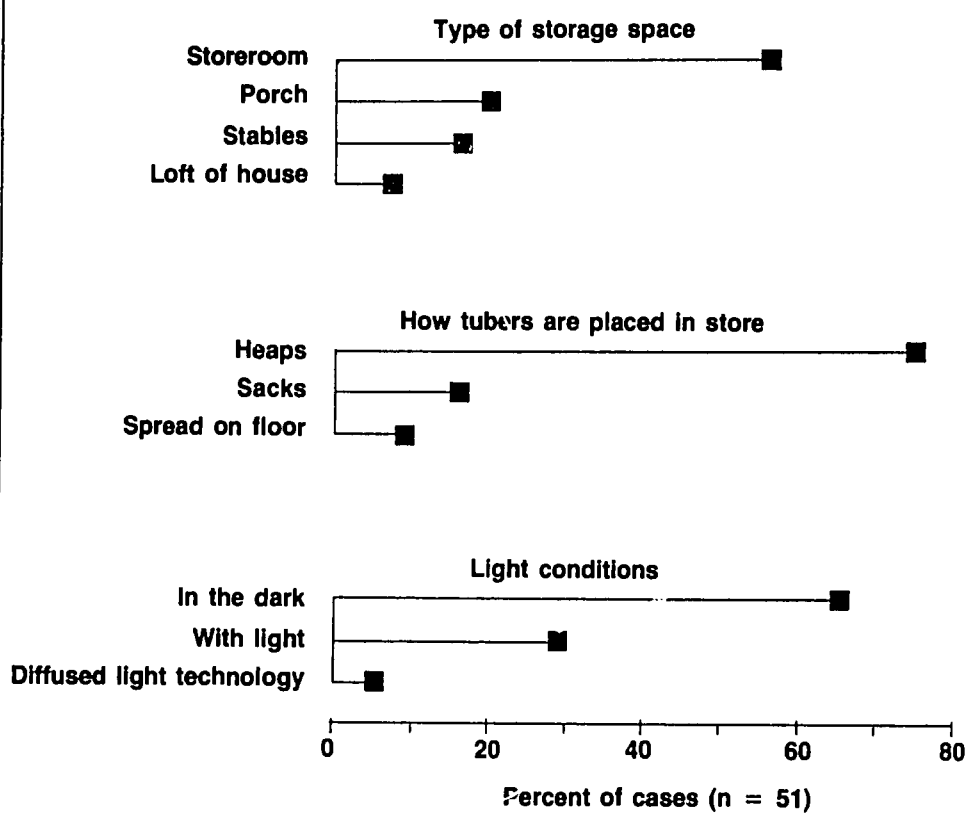


Figure A9. Cañete Valley: Distribution of sample potato farmers by size categories, 1985

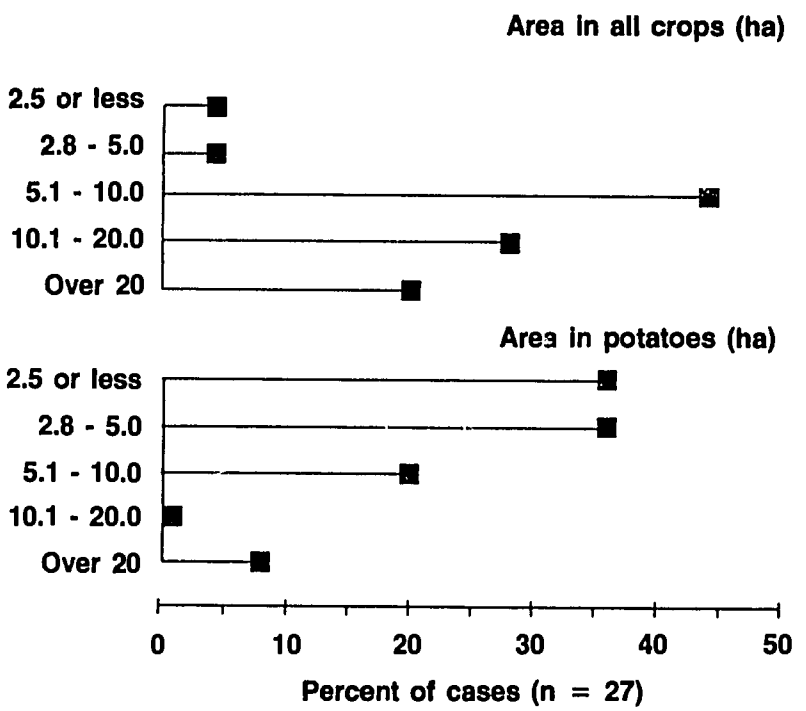


Figure A10. Cañete Valley: Potato varieties and other crops grown by sample farmers, 1985

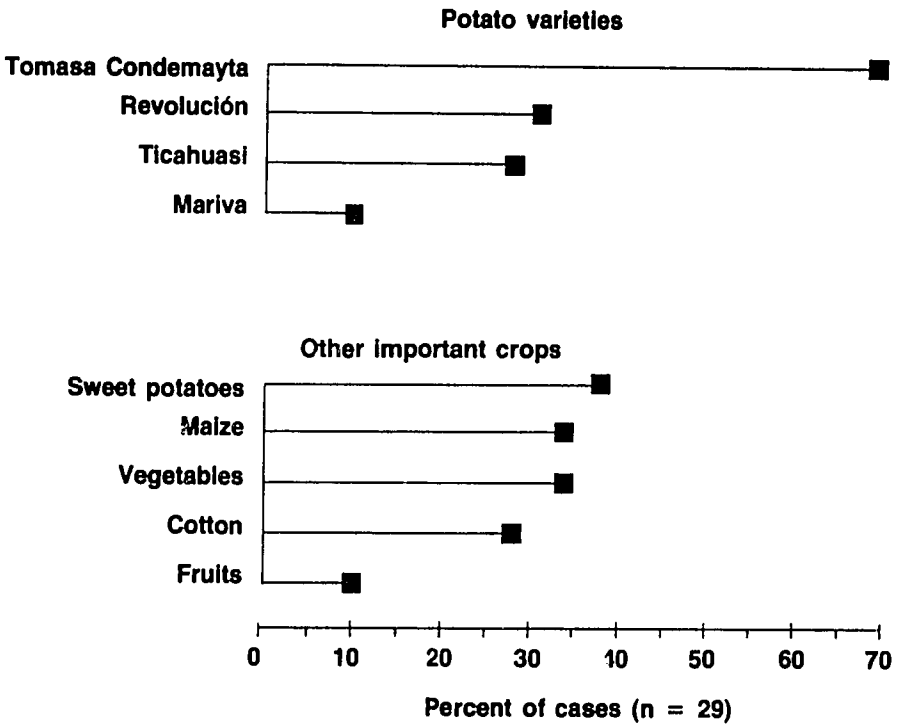
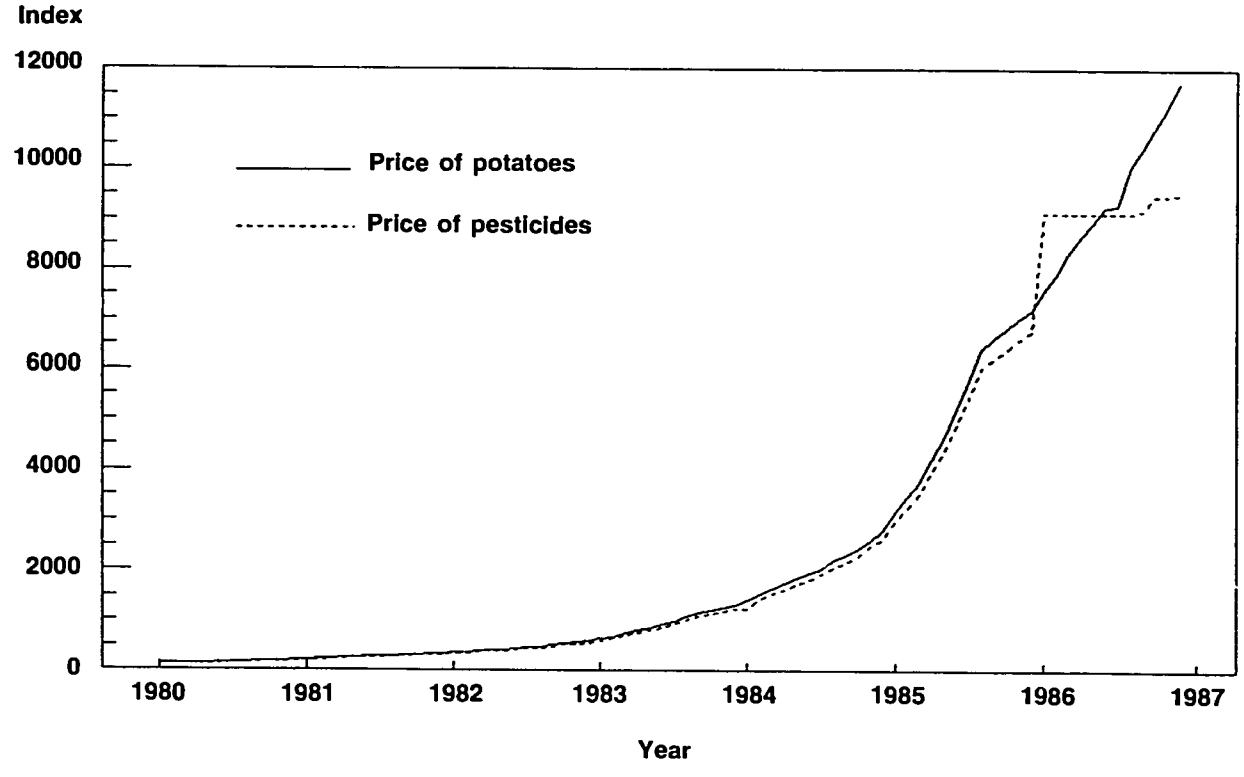


Figure A11. Peru: Indices of wholesale potato prices and pesticide prices, 1980-1986, 1980 = 100



Source: Peru, INIAA, Oficina de Agroeconomía

Photo A1. Cuzco farmer identifying pests in a box of specimens

Photo A2. Highland farmer applying insecticide with a straw brush (brocha de paja)

References

Achata, A., H. Fano, H. Goyas, O. Chiang, and M. Andrade. In Press. El Camote (*Ipomoea batata* L.) en el Valle de Cañete, Peru. Lima: Centro Internacional de la Papa.

Alcalá, P. 1981. "Insectos de la papa en el valle del Mantaro" (Huancayo, Peru: Estación Experimental Agrícola Huancayo y el Centro Internacional de la Papa (CIP)).

Alcalá, P. y J. Alcázar. 1976. "Biologia y comportamiento de *Premnotrypes suturicallus* Kuchel (Col.: *Curculionidade*)." Revista Peruana de Entomología. 19: 49-52.

Altieri, M.A. 1984. "Pest management technologies for peasants: a farming systems approach.". Crop Protection 3: pp. 87-94.

Booth, R.H., R.L. Shaw, and L.J. Harmsworth. 1981. Potato Storage for Developing Countries. Lima: International Potato Center (CIP).

Boza, T. 1972. "Ecological consequences of pesticides used for the control of cotton insects in the Cañete Valley, Peru," in M.T. Farvar and J.P. Milton, Eds., The Careless Technology--Ecology and International Development (Garden City: Natural History Press), pp. 423-438.

Brader, L. 1979. "Integrated pest control in the developing world." Annual Review of Entomology. 24: 225-254.

Brown, B.J. 1986. "The ecology of traditional pest management in Southeast Asia." In Marten, G.G., Ed., Traditional Agriculture in Southeast Asia (Boulder and London: Westview Press), pp. 241-272.

Brush, S.B., H.J. Carney, Z. Huamán. 1981. "Dynamics of Andean potato agriculture." Economic Botany, 35 (1), pp. 70-88.

Cáceda, F. and J. Rossel. 1984. Entomología de los Cultivos Andinos (Puno, Peru: Universidad Nacional del Altiplano).

Campos, R. 1979. "Control químico de la "mosca minadora" (*Liriomyza huidobrensis*) en el Valle de Cañete." Revista Peruana de Entomología. 21: 109-112.

Carrasco, F. 1961. "Sistemática y biología del gorgojo de los Andes, *Premnotrypes laththorax* Pierce 1914 (Col.: *Curculionidae*). Revista Peruana de Entomología Agrícola. 4: 30-42.

Cisneros, F. 1984. "The need for integrated pest management in developing countries.: In: Report of the XXII Planning Conference on Integrated Pest Management. (Lima: International Potato Center (CIP)), pp. 19-30.

Delgado, M. 1980. "Control de la mosca minadora en el cultivo de la papa." (Lima: Ministerio de Agricultura).

Fano, H. 1983. "Cambio tecnológico y tendencias de la producción de papa en la región central del Perú, 1948'1979." Tesis Msc. Lima: Universidad Nacional Agraria La Molina.

Fano, H., J. Alcázar, and M. Palacios. 1985. "Nombres locales de las plagas insectiles de la papa: Aproximación al conocimiento campesino." Mimeograph. (Lima: International Potato Center (CIP)).

Fano, H. and P.T. Ewell, 1986, "El control de plagas en papa en la sierra del Perú," Sur: Boletín Informativo Agrario (Cusco, Peru), Año 9, No. 96, pp. 40-46 and No. 97, pp. 44-47.

Franco, E., C. Moreno, and J. Alarcón. 1983. "Producción y utilización de la papa en la región del Cusco" (Lima, Centro Internacional de la Papa (CIP)).

Franco, E., D. Horton, R. Cortbaoui, F. Tardieu, annd L. Tomassini. 1981. Evaluación Agro-económica de Ensayos Conducidos en Campos de Agricultores en al Valle de Mantaro (Peru) Campaña 1978/79. Documento de Trabajos 1981-1. (Lima: International Potato Center (CIP)).

Glass, E., H.D. Thurston. 1978. "Traditional and modern crop protection in perspective." BioScience, 28 (2), pp. 109-115.

Hererra, J. 1963. "Problemas insectiles del cultivo de la papa en el Valle de Cañete." Revista Peruana de Entomología Agrícola, 6 (1), pp. 1-9.

Horton, D. 1984. Social Scientists in Agricultural Research: Lessons from the Mantaro Valley Project, Peru (Ottawa: International Development Research Center (IRDC)).

Horton, D. 1988. Underground Crops: Long-term Trends in Production of Roots and Tubers. (Morrilton (U.S.A.): Winrock Unternational Institute for Agricultural Development).

Kenmore, P.E., J.A. Litsinger, J.P. Bandong, A.C.Santiago, and M.M. Salac. 1987. "Philippine rice farmers and insecticides: thirty years of growing dependency and new options for change." In J. Tait, B. Napompeth, eds., Management of Pests and Pesticides: Farmers' Perceptions and Practices (Boulder and London, Westview Press), pp. 98-108.

Matteson, P., M. Altieri, and W. Gagné. 1984. "Modification of small farmer practices for better pest management." Annual Review of Entomology 29, pp. 383-402.

Mayer, E. 1979. Land Use in the Andes: Ecology and Agriculture in the Mantaro Valley of Peru, with Special Reference to Potatoes. (Lima, International Potato Center (CIP)).

Mayer, E. and M. Glave. In preparation. "Papas regalo y papas regalados: Rentabilidad, costos, e inversión. Champaign (U.S.A.): Latin American Program, University of Illinois, and Washington, D.C.: The Wilson Center.

Meza Rojas, D.A. 1978. "Evaluación de plagas insectiles en variedades comerciales de papa." Thesis. Ing. Agrónomo. Universidad Nacional del Centro del Peru, Huancayo. 51 p.

Midmore, D. 1986. "Respuesta de la planta de la papa al daño de insectos: algunas efectos de compensación." in L. Valencia, ed., Control Integrado de Plagas de Papa (Bogotá: Centro Internacional de la Papa (CIP)), pp. 176-201.

Monares, A. 1979. Agro-economic Evaluation of Highland Seed in the Cañete Valley, Peru. Working Paper 1979-3. (Lima: International Potato Center (CIP)).

Peralta, T., and G. Javier. 1980. "Control integrado de las plagas de la papa en el Valle del Mantaro." Revisa Peruana de Entomología. 23: 133-137.

Prain, G.D. In preparation. "Peasant seed potato systems in the central highlands of Peru." (Lima: International Potato Center (CIP)).

Raman, K.V. 1988. "Integrated insect pest management for potatoes in developing countries." CIP Circular. 16: 1-8.

Raman, K.V., R.H. Booth and M. Palacios. 1987. "Control of potato tuber moth *Phthorimaea operculella* (Zeller) in rustic potato stores." Tropical Science. 27: 175-194.

Raman, K.V., R.H. Booth. 1984. "Integrated control of potato tuber moth in rustic potato stores." In: Proceedings of the 6th Symposium of the International Society for Tropical Root Crops held at CIP-Lima, Peru, Feb. 21-26, 1983. (Lima: CIP) pp. 509-515.

Rhoades, R.E, M. Benavides, J. Recharte, E. Schmidt, and R. Booth. 1988. Traditional Potato Storage in Peru: Farmers' Knowledge and Practices. (Lima: International Potato Center (CIP)).

Rhoades, R.E., M. Benavides, and J. Recharte. In preparation. "The farmers of Cañete: land use and cropping strategies in a Peruvian coastal desert valley." (Lima: International Potato Center (CIP)).

Richards, P. 1980. "Community environmental knowledge in African rural development." In D. Brokensha, D.M. Warren, O. Werner, eds., Indigenous Knowledge Systems and Development (Lanham, Md., University Press of America), pp. 181-194.

Sánchez, G.A., V. Aquino, and Raúl Aldana. 1986. "Contribución al conocimineto de *Symmeterischema plaesiosema* (Lep.: *Gelechiidae*)." Revista Peruana de Entomología 29: 89-93.

Scott, G. 1985. Markets, Myths, and Middlemen: A Case Study of Potato Marketing in Central Peru. (Lima: International Potato Center (CIP)).

Tait, J. and Napompeth B., Eds. 1987. Management of Pests and Pesticides: Farmers' Perceptions and Practices. (Boulder: Westview Press).

Valencia, L. 1984. Insectos que Atacan la Papa. (Lima: International Potato Center (CIP)).

von Arx, R., J. Goueder, M. Cheikh, and M. Ben Temime. 1987. "Integrated control of potato tuber moth Phthorimaea operculella (Zeller) in Tunisia" Insect Science and it Applications. 8: 989-994.

von Arx, R., P.T. Ewell, J. Goueder, M. Essamet, M. Cheikh, and A. Ben Temine. 1988. 'Management of the potato tuber moth by Tunisian farmers" (Lima, International Potato Center (CIP)).

Werge, R. 1977. Potato Storage systems in the Mantaro Valley Region of Peru. (Lima, International Potato Center (CIP)).

Wille, J.E. 1952. Entomología Agrícola del Perú. (Lima, Perú, Ministerio de Agricultura).

Yábar, E. 1986a. "Control de larvas de "gorgojo de los andes" mediante almacenamiento de papa con luz difusa." Revista Peruana de Entomología 29: 95-97.

Yábar, E. 1986b. "Estado actual del conocimiento sobre la mosca minadora de la papa." Ms. Lima: Universidad Nacional Agraria La Molina.

Yábar, E. 1986c. "Estudios de resistencia a mosca minadora (*Liriomyza huidobrensis*)." In Memorias de la V Reunion Anual de PRACIPA (Cochabamba, Bolivia: PRACIPA).

Yábar, E. 1988. "Integración de practicas culturales para el control del Gorgorgo de los Andes (*Premnotrypes spp.*) Revista Latinoamericana de la Papa. 1: 120-131.

Yamamoto, N. 1985. "Investigación preliminar sobre las actividades agro-pastoriles en el distrito de Marcapata, Departamento del Cuzco, Peru." in S. Masuda, Ed. Estudios Etnográficos del Perú Meridonial (Tokio: Universidad de Tokio), pp. 85-137.

Yamamoto, N. In preparation. "Traditional Andean Potato Processng." (Lima: International Potato Center (CIP)).