

Integrated Pest Management in the Global Arena

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Chapter 23

Integrated Pest Management in Peru

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History and Evolution of IPM in Peru

Peru was the site of one of the first large-scale IPM programs. In the early 1950s, the German–Peruvian entomologist Johannes Wille developed the concept that agricultural entomology was a branch of applied ecology, and recommended that insecticides be used only as a last resort (Wille, 1952). IPM in Peru began in the mid-1950s in response to problems caused by the use of organochlorines on crops such as cotton, citrus, olives and sugarcane (Risco, 1954, 1960; Herrera, 1961; Beingolea *et al.*, 1969; Beingolea and Salazar, 1970).

Cotton

An IPM program for cotton in the Cañete valley began in the mid-1950s after a period of intensive use of organochlorines (DDT, BHC, toxaphene and aldrin) from 1949 to 1956. Problems resulting from the overuse of insecticides were the development of insecticide resistance, pest resurgence, and appearance of new pests due to the elimination of natural enemies. In 1955–1956, cotton production collapsed, and the Farmers' Association of the Cañete Valley organized an IPM program with technical support from the government. This program banned the use of synthetic insecticides and initiated a program for biological restoration of the valley (Herrera, 1961). The biological restoration program was facilitated by the fact that cotton, its insect pests and the complex of natural enemies are all native to Peru. The IPM program was soon expanded to all coastal valleys of the country. In each valley, farmers' associations were promoted and plant protection services were established.

Citrus

By 1961, insect pests in citrus had become a major problem due to the use of organophosphate insecticides. Initially, alternative strategies for managing citrus pests included the use of selective insecticides and the release of natural enemies (Beingolea, 1961). Since citrus and many of its insect and mite pests had been

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introduced into the country, the lack of effective natural enemies was understandable. Several beneficial insects were introduced successfully, as demonstrated in the rehabilitation of an 8-year-old citrus orchard in the Chincha valley (Central Coast of Peru) that had been severely infested by pests after frequent applications of insecticides (Beingolea *et al*., 1969).

Olives

Biological control of olive pests began in 1937 with the first introductions of natural enemies of the black scale, *Saissetia oleae* (Wille, 1952). This system, with some fluctuations, was maintained until 1954. In that year, major outbreaks of the black scale occurred in some olive-producing areas, induced by the intensive use of insecticides such as parathion and azinphos-methyl. Following these outbreaks, an integrated management system was established for olives. Integrated management of olive pests was based on the action of predators and cultural measures to increase mortality and improve the effectiveness of parasitoids. An effective monitoring system, mass-rearing of natural enemies and the use of high-pressure sprayers were all part of the integrated program, among other practices (Beingolea, 1993).

Sugarcane

Significant losses from the sugar cane borer, *Diatraea saccharalis* in 1949 induced farmers to try new measures for the management of this pest. In 1951, the parasitoid, *Lixophaga diatraea* was introduced into the country. However, this species was not successfully established. Conversely, the mass release of a native parasitic fly *Paratheresia claripalpis* reduced by 83% the damage in sugarcane as a result of high levels of parasitism (88%) (Risco, 1954, 1960). During the Agrarian Reform in the 1970s, large sugarcane farms became cooperatives and the pest management program was significantly impaired due to new government policies (Pollack, 1994).

IPM education

In 1971, graduate programs (MSc level) in entomology and plant pathology were initiated at the National Agrarian University 'La Molina'. Important concepts of IPM were taught, for instance, Cisneros (1980) defined IPM as integrating insect pest, disease, and weed management, and emphasizing the inclusion of two or more pest control techniques based on economic damage level. Pest control techniques should be ecologically and economically sound, minimizing undesirable effects.

Policies and legal issues related to IPM

As early as 1909, Peru passed a law related to Plant Protection. This law was modified and expanded in 1949. In 1976, a newly created Ministry of Food issued a Plant Sanitation Regulation for importation and exportation of plant products. In 1993, a plant sanitary certificate from the country of origin became a requirement for the introduction of plant products. A law issued in 1997 promotes IPM as the major policy in agriculture. Several other policies also affect IPM implementation directly or indirectly.

In recent years, the Government of Peru has reinitiated technical assistance to farmers through special programs that included the extension of IPM. These programs include PRONAMACHCS (a national program for the management of soils and watersheds), and SENASA (the national service for plant and animal health).

Organizations Involved in IPM in Peru

Three types of institutions develop IPM research and extension in Peru: public institutions and universities, farmers' associations, and private organizations (Table 23.1).

Table 23.1. Institutions that do research, extension and set regulations for IPM techniques in Peru.

		Methods of control								
	Institutions	Cultural	Biological	Behavioral	Use of varieties	Plant breeding	Physical or mechanical	Chemical or botanical	Legal	IPM
Research	INIA	X	X		X			X		
	University						X	X		
	CIP	X	X	X	X	X		X		X
Farmers as IPM clients	Cotton	X	X	X	X		X	X	X	X
	Citrus	X	X	X			X	X		X
	Potatoes	X	X	X	X	X	X	X	X	X
Institutions involved in IPM extension	INIA	X	X		X	X	X		X	X
	University	X	X	X	X		X	X	X	X
	CIP	X	X	X	X	X	X	X	X	X
	NGOs	X	X	X	X		X	X	X	X
	SENASA	X	X	X	X		X	X	X	X
Regulatory Institution	SENASA	X	X			X		X	X	X
Institutions providing IPM inputs	SENASA		X							X
	Industry		X							
	CIP		X	X		X				X
	NGOs		X	X				X		X
	INIA		X		X					X

Public institutions

Research institutes

The first experiment station was established in La Molina in 1946, with several departments including entomology and plant pathology (Vilchez, 2000). In 1981, a National Institute for Agricultural Research and Promotion was created with a research program in entomology. Later on, this program has since been superseded by an INIA with four major research programs, one of which is the National Research Program for IPM.

In 1989, research began on the use of hydrothermal treatments of export mangos for the immature stages of the Mediterranean fruit fly, *Ceratitis capitata*. As a result, the USA approved the importation of mangos from Peru in 1991. Research on the control of the fruit flies *Ceratitis capitata* and *Anastrepha fraterculus* has continued with techniques such as mass releases of sterile flies, use of traps for monitoring, biological control, cultural control, and chemical control. Other research programs have included testing the efficacy of sticky yellow traps for leafminer flies and whiteflies, and the identification of several entomopathogenic fungi including *Neozygites*, *Verticillium lecanii*, *Pandora neoaphidis*, *Entomophthora planchoryana*, *Conidiobolus*, *Erynia* spp., *Erynia dipterigena*, Zoop Tera *phalloides* in crops such as coffee, citrus, tomato, potato, cucumbers and beans.

The biological control work has been conducted in two geographic areas: in the mountains and in the coast area. In the mountains, research and extension activities were carried out on the utilization of entomopathogens including *Beauveria bassiana* and *B. brongniartii* for the control of the Andean potato weevil; Baculovirus for the control of potato tuber moths; rearing and release of *Campoletis* sp. for control of larvae of Lepidoptera; *Copidosoma koehleri* for the control of tuber moth; and *Pachycrepoideus* spp. for fruit flies. In the coast area, research was concentrated on the use of entomopathogenic fungi; *Verticillium lecanii* and *Paecilomyces farinosus* for the control of whiteflies (*Bemisia tabaci* and *Aleurodicus cocois*) in cotton, cowpea, cucumber, melon, watermelon, and mango. *Metarhizium anisopliae* and *Beauveria bassiana* were used for the control of the diamondback moth, *Plutella xylostella*, and the antagonistic fungus, *Gliocladium roseum* for the control of the strawberry gray rot, *Botrytis cinerea*.

Universities

Research conducted at the universities focused on the development of IPM components. Sixteen agronomy faculties throughout the country are involved in basic and applied research related to IPM (Arroyo, 1988, 1989). These projects are most often related to thesis research required to obtain undergraduate degrees. For instance, in 1995, 75% of thesis research projects were related to the chemical control of insect pests at the Agrarian University at La Molina (Lizárraga *et al.*, 1995). However, in the past 5 years, research on biological control, host plant resistance, and other non-chemical measures has been given more importance.

Farmers' associations

Research in agriculture was initiated by the farmers belonging to the National Agrarian Society. In 1926, farmers of the Cañete valley founded an experiment station designed to increase productivity in export crops such as cotton and sugarcane. The pest resistance in cotton inspired research to explain the factors associated with increased pest populations and to develop new methods of control. This work established a foundation for IPM in Peru.

In the 1970s, due to change in the government policy, the Agrarian Reform truncated this unusual system of 'farmers promoting research for the control of pests'. Currently, only large agricultural enterprises with adequate economic resources can provide facilities for research related to the development of IPM.

International programs and local NGOs

FAO and NGOs

In 2000, a special IPM project known as 'Integrated Pest Management in Major Food Crops of Peru' was implemented. This project has been sponsored by FAO and run by several governmental and non-governmental organizations, including SENASA, INIA, PRONAMACHS, UNALM, Catholic Agency For Overseas Aid and Development, CARE (Network of relief and development organizations) and RAAA. The major objective of this program is to improve the quality of life of small farmers in Peru, by increasing their income, reducing pesticide exposure and promoting sustainable production. The program was patterned after the highly successful FFS approach. As a result of this training, many farmers, especially potato and cotton producers, will be able to implement IPM in their fields.

The CIP

In 1971, the CIP was created to generate improvements in potato production. CIP has contributed to the development of potato IPM, particularly in the management of nematodes, fungi and insects. Initially, research emphasized the development of resistant plants. From 1978 until 1990, CIP's entomological research was focused on the management of three key pests: the Andean potato weevil, *Premnotrypes* spp., the potato tuber moth, *Phthorimaea operculella* and the leafminer fly, *Liriomyza huidobrensis* (Raman and Palacios, 1983; Ramau, 1984, 1987, 1988a,b).

In 1988, CIP organized the first IPM Pilot Unit, and within 2 years Pilot Units were established in several areas of the country. Pilot Units demonstrate the use of IPM strategies in farmers' communities, and help train farmers, extension workers and professionals involved in potato cultivation. Since 1998, new research findings have been incorporated into the system to improve IPM implementation. In 1999 CIP initiated a study of alternatives for the management of potato late blight and the possibility of using the FFS approach, sponsored by FAO, as a training method.

Until 1990, CIP's research findings were transferred to the National Potato Program of the INIAA for on-site testing and demonstration of management strategies. Since 1992, these functions have been passed to other organizations, primarily NGOs. NGOs working in rural areas have partially replaced the role of the Peruvian Government in technology transfer among farmers. Several organizations are involved in these activities. In general, NGOs are not involved in research, except for those that are working on specific projects in collaboration with universities or other research institutions such as CIP.

To raise awareness of IPM programs and management strategies, CIP produces a variety of materials (bulletins, videos, posters, and portfolios). Major components of these management programs include cultural practices, use of sex pheromones, colored traps, shelter and food traps, and the introduction and protection of natural enemies (Cisneros *et al*., 1995).

Successful Cases of IPM

Peru has a long history of successful IPM programs. The most well-known is the integrated management of cotton pests, begun in the mid-1950s and still in practice today. More recently, integrated management of potato pests has been implemented with the support of the CIP.

Integrated management of cotton pests

Cotton has been grown in Peru for over 5000 years. On the northern coast, the varieties Pima and del Cerro are grown. On the central and southern coasts, the most common variety is Tangüis, which is resistant to wilting disease. In the north and central jungle, a native white to red colored cotton (algodón áspero) is cultivated in small areas. Cotton in the coast is irrigated (surface irrigation), whereas cotton in the jungle is grown under rainfall conditions.

In recent years, cotton production has varied between 145,000 t and 268,000 t. The area under cultivation has also varied, from 73,000 ha to 137,000 ha (Perú Acorde, 2000). Currently, most cotton is grown on small farms of 1–3 ha. Only a few producers grow 50–500 ha.

Major cotton pests

Major pests of cotton in Peru are the cotton stainer, *Dysdercus peruvianus*, the cotton leaf perforator, *Bucculatrix thurberiella*, the Peruvian bollweevil, *Anthonomus vestitus* and the Indian pink bollworm, *Pectinophora gossypiella*. Other pests include mites, *Eriophyes gossypii*, armyworms, the cotton plant crown weevil, *Euthinobotrus gossypii*, the cotton aphid, *Aphis gossypii*, and other insects that feed on leaves, squares, flowers and bolls (*Anomis texana*, *Alabama argillacea*, *Mescinia peruella*, *Pococera atramentalis*, *Heliothis virescens*).

Control methods

Pest management in cotton is primarily applied against insects, since disease and weed problems are minimal. Control methods used in the integrated management of cotton pests vary, but emphasis is placed on cultural, legal and biological control. Management strategies for the cotton pests in Peru had been reviewed by Herrera (1998) and González (2000) (Table 23.2).

Cotton IPM is based on the knowledge of plant phenology, use of biological control agents, correct timing, planting deadlines and managing of the irrigation. This program has allowed cotton to be grown without the use of pesticides (i.e. organic production). IPM for organic cotton production also uses measures such as a fallow period, use of local varieties, certified seed, and adequate use of irrigation and fertilization (Morán *et al.*, 1999). Other treatments include the use of Bt, rotenone, natural oils, pheromones, copper sulfate, sulfur, and releases of *Trichogramma*.

Scouting is essential for decision making and for using preventive measures. In cotton agroecosystems, parasitoids, predators and entomopathogens are important pest mortality factors. It would be impossible to cultivate cotton without the regulating action of beneficial insects (Herrera, 1998). The implementation of an IPM program in cotton including the release of *Trichogramma* spp. and use of pheromone traps for the Indian pink bollworm reduced by 70% the use of pesticides on more than 500 ha of small farms in the Ica valley (Castro *et al.*, 1997).

In recent years, the populations of the silver leaf whitefly, *Bemisia argentifolii*, has increased due to climatic changes linked to the El Niño phenomenon. Fortunately, the whitefly population was reduced by an epizootic due to two fungi, *Paecilomyces fumosoroseus* and *P. farinosus*.

In organic cotton in the Cañete Valley, the use of good cultural practices together with sprays of Bt, rotenone, oils, pheromones, sulfur and release of *Trichogramma* wasps reduced cost of production by 50% (Van Elzakker, 1999).

Integrated pest management of potato pests

Geographical distribution of the potato crop

The potato was first domesticated near Lake Titicaca (between Peru and Bolivia). It is a staple food for about 8 million Peruvians and a source of income for farmers. The potato is grown from sea level to altitudes higher than 4200 m. The potato growing area varies from 200,000 to 320,000 ha. About 80% of this area is located in the higher sierra (above 3000 m), 15% at medium altitude (500–3000 m) and 5% at the coast (0–500 m).

HIGH ALTITUDES Small-scale farmers at higher altitudes have the lowest yields (3–4 t/ha). The production technology is largely traditional, but some farmers are beginning to use modern techniques. At high altitude, potato production occurs during the rainy season (September to June). The major pest is a complex of Andean potato weevil species (*Premnotrypes latithorax*, *P. suturicallus* and *P. vorax*).

Table 23.2. Components of the Peruvian model of IPM for cotton pests (adapted from González, 2000).

Pest		
Common name	Scientific name	Control measure
Armyworms	*Agrotis ypsilon* Roll *Prodenia eridania* Cramer *Prodenia ochrea* Hampson *Spodoptera frugiperda* Sm	Poisoned baits Heavy irrigation Minimum tillage Light traps
Whiteflies	*Bemisia tabaci* *B. argentifolii*	Entomopathogens Irrigation management Oil and rotenone Not planting near infested fields Organic fertilizers Not planting hybrid cotton
Cotton crown weevil	*Eutinobothrus gossypii* Pier.	Avoiding ratoon cotton (SENASA supervision) Domestic quarantine Light traps
Aphids	*Aphis gossypii* Glov.	Protection of natural enemies: predators and parasitoids
Peruvian weevil	*Anthonomus vestitus* Bohm.	Avoiding ratoon cotton Deadline for crop residue destruction Avoiding excessive foliage Destruction of pest-hosting weeds Topping (Piura); goat feeding (Pisco) Deadlines for planting Picking infested squares and placing them in cages to recover parasitoids
Leafworms	*Anomis texana* Riley *Alabama argillacea* (Hub)	Use *Bacillus thuringiensis* Protect natural enemies: predators Release *Trichogramma* spp. Light traps
Small bollworm	*Mescinia peruella* Schauss	Protect natural enemies Picking of dried flowers Light traps
Boll-end worm	*Pococera atramentalis*	Protect natural enemies Picking of dried flowers Avoid maize fruiting at the time of cotton fruiting Light traps
Bollworm	*Heliothis virescens* (Fab.)	Protect natural enemies Apply *Bacillus thuringiensis* in terminals Release *Trichogramma* spp. Irrigation management Light traps
Pink bollworm	*Pectinophora gossypiella* S.	Release of *Trichogramma bactrae* Light traps

continued

Table 23.2. *Continued.*

Pest		
Common name	Scientific name	Control measure
Cotton leaf perforator	*Bucculatrix thurberiella* B.	Protect natural enemies Organic fertilization
Cotton stainer	*Dysdercus peruvianus* Guer (remaining populations)	Frequent hand picking Destroy host plants Comply with ‘clean field’ regulations Poisonous baits with crushed cotton seed Light traps
	(migratory populations)	Destroy focal infestation in the upper valley Comply with ‘clean field’ regulations Destroy host plants (guava, loquat, aubergine, tomato, etc.)

MEDIUM ALTITUDES (INTER-ANDEAN VALLEYS) In the inter-Andean valleys, potato yields are highest (50–60 t/ha). Irrigated potato production occurs from July to February. The potato tuber moth complex (*Symmetrischema tangolias* and *Phthorimaea operculella*) is the predominant pest.

LOW ALTITUDES (THE COAST) Yields on the coast average 25 t/ha. Potato production is irrigated and uses modern technology, including high chemical inputs (Ewell *et al.*, 1990; Egúsquiza, 2000). The most important pest is the leafminer fly, *Liriomyza huidobrensis*. At the coast and at the mountains, the most important disease is the late blight, *Phytophthora infestans*.

Potato pests

ANDEAN POTATO WEEVIL The Andean potato weevil is endemic to the high areas of the Andean region (Peru, Bolivia, Ecuador, Colombia and Venezuela). The larva is the most damaging stage of this pest. When infestations are high, losses of more than 50% have been reported (Raman, 1984; Alcázar and Cisneros, 1997). In areas of intensive potato production where insecticides such as carbofuran, parathion, aldicarb and methamidophos are used, damage can reach 20–30% (Alcázar and Cisneros, 1997).

In Peru, the Andean potato weevil has only one generation per year. Adult weevils feed on leaves. The female lays eggs on wheat, barley or other plant debris. Larvae tunnel inside the tubers and then pupate in the soil. The adult has two phases: a diapausing phase in the soil and an active phase on the crop. The diapausing phase lasts about 4 months. Adults start emerging from the soil after the first rains and live from 4 to 5 months.

POTATO TUBER MOTH The tuber moth, *Phthorimaea operculella*, is an important pest in warm areas of the world where potato is cultivated. In Peru, this pest occurs at a wide range of altitudes. During the last decade, populations of another tuber moth species, *Symmetrischema tangolias*, have increased significantly at altitudes between 2500 and 4000 m (Palacios and Cisneros, 1997). Both species damage tubers in the field and in storage. Tuber damage is around 30% in the field and above 50% in storage. The larvae also damage the stems and leaves. Damage caused by *P. operculella* has no significant effect on yield, but tunnels produced by *S. tangolias* in potato stems can reduce yield depending on the potato variety. The populations of both species can increase significantly under dry and warm conditions. Farmers use toxic chemicals against this pest such as parathion, aldrin, foxim, malathion, methamidophos, propoxur and deltamethrin (Ewell *et al.*, 1990; Palacios and Cisneros, 1997).

The duration of the potato tuber moth life cycle varies with environmental conditions. At high and medium altitudes, the life cycle takes 2–4 months, with three to five generations per year. At lower altitudes, the life cycle is shorter and six to ten generations may occur in a year.

THE LEAFMINER FLY The leafminer fly, *Liriomyza huidobrensis*, has become a pest particularly in the Cañete valley, where the crop is grown intensively outside of its native range. This pest damages the leaves by larvae feeding or female oviposition. Larvae feed on the parenchyma and make serpentine tunnels. Mined leaves dry out and photosynthesis and yields are affected. Yield loss due to this pest is around 30–40%. To control this pest, farmers in the Cañete valley typically make 8–13 insecticide applications. This intensive use of chemicals has caused the development of insecticide resistance to carbamates, organophosphates and pyrethroids.

SECONDARY PESTS Secondary pests including the budmidge, *Prodiplosis* sp., the white mite, *Poliphagotarsonemus latus*, and whiteflies have been observed in recent years in several crops, including potato (Mujica and Cisneros, 1997). The whitefly is a polyphagous pest, with four to five generations per year, that infests a great number of cultivated and ornamental plants and weeds, which favors the presence of the pest the whole year.

Integrated management

Potato IPM is based on the knowledge of biology and pest behavior, seasonal occurrence, spatial distribution and plant phenology. The principal strategies rely on cultural, behavioral, and biological control methods. These methods have to be applied preventively to avoid economic damage both in the field and storage, pest migration from the field to the storage area, multiplication of the pest in plant residues, volunteer potatoes and alternate hosts (Table 23.3). In the design of IPM, several IPM strategies are available for farmers according to their needs (Cisneros, 1995; Alcázar and Cisneros, 1997; Mujica and Cisneros, 1997; Palacios and Cisneros, 1997; Cisneros *et al.*, 2001).

IPM technology transfer to farmers: Pilot Units

The CIP has defined phases of development for IPM programs, from initial evaluation to application by farmers in the field (Cisneros *et al.*, 1995). IPM training in Pilot Units is designed to first identify farmer knowledge gaps in relation to pests and control methods, so that training is focused on filling these gaps and reinforcing prior knowledge (Ortiz *et al.*, 1997). The implementation of IPM in Pilot Units and its extension by CIP and collaborating NGOs had resulted in the training of 37,702 farmers covering 15,098 ha, which corresponds to about 6% of the potato growing area (Alcázar, Palacios and Ortiz, personal communication). IPM in Pilot Units has resulted in a significant reduction of key potato pest damage and a reduction in the use of insecticides (Cisneros *et al.*, 1998). Currently, the IPM strategies developed by CIP to manage potato pests are being expanded to all the country by various institutions. These IPM programs have been used as models in the Andean region (Bolivia, Ecuador, Colombia and Venezuela) and the Caribbean region (Dominican Republic).

Final Comments

The successful Peruvian cotton IPM program, begun in the 1950s, has now been extended to various other countries. Currently, IPM in export crops such as cotton, citrus, sugarcane, mango and asparagus has improved marginal profits for Peruvian producers. In crops for domestic consumption such as potato, IPM has improved the food supply for the Andean population. In addition, it has reduced the risk of pesticide exposure, pesticide residues in food and in the environment. Potato IPM has also socially impacted the resource-poor farmers on Peruvian mountains. Many of these mountain communities are now practicing IPM strategies adapted to local conditions.

Table 23.3. IPM strategies for key pests of potato in Peru.

Andean potato weevil	Potato tuber moth	Leaf miner fly
Population reduction in the field	Crop protection: planting – harvest	Population reduction in the field
Early planting Healthy seed Weevil hand picking Destroy volunteer plants Harvest timely	Good plowing Planting timely Good coverage of seed High hilling Pheromone traps Frequent irrigation Use selective insecticides	Good quality seed Yellow sticky traps Appropriate irrigation Increase natural enemies Use selective insecticides Destroy harvest residues
Interruption of weevil migration	Protection of harvested tubers	Interruption of fly migration
Plant barriers Chemical barrier Perimeter trenches Bait traps Use sheets at harvest Store in diffuse light	Harvest timely Tuber sorting Cover harvested tubers Destroy harvest residues	Avoid neighboring fly-host crops
Reduction of wintering population	Protection of stored tubers	
Plowing soil where tubers piled up at harvest Winter plowing of harvested field	Cleaning and disinfestations of stores Use baculovirus Use repellent plants Store in diffuse light Check stored tubers periodically	

Several organizations, both public and private, participate in the development and transfer of IPM strategies in Peru. Communication and coordination between these groups is occasionally limited. The lack of farmer organizations also limits a rapid IPM implementation, leaving pesticides as a major management strategy. In Peru, IPM is a model that despite some social and economic constraints has evolved to offer several pest management alternatives.

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