Chapter 1

Implementation and Adoption of Integrated Pest Management Approaches in Latin America: Challenges and Potential

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Additional information is available at the end of the chapter

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Abstract

Latin American countries present diverse agricultural systems, ranging from the subsistence agriculture in common property lands to large highly mechanized estates that produce crops for export. Despite this diversity, the adoption of integrated pest management (IPM) is commonly based on reducing the negative effect of pesticides on consumer health and on the environment. In most of Latin American countries, the agricultural sector is characterized by poor infrastructure in research and extension systems, a public sector with limited human resources that limits the dissemination of information and provides inappropriate credit and subsidy schemes, all of these have influenced negatively on the possibility of the success of IPM programs. Thus, some innovative alternatives have emerged from concerning public and private initiatives. In this regard, the Plantwise approach, as a framework for action, is to strengthen the capacity of agricultural institutions and organizations to establish more effective and sustainable national plant health systems. Plantwise is an innovative global program led by the Centre for Agriculture and Biosciences International (CABI), which aims to contribute to increased food security, alleviated poverty, and improved livelihoods by enabling male and female farmers around the world to lose less, produce more, and improve the quality of their crops. Strengthening plant health systems removes barriers to make accessible to farmers sustainable approaches for pest control. In this chapter, we include some historical review of IPM concepts, strategies, and some experiences in application of IPM in Latin America. Also we discuss the potential and challenges for implementation and adoption of IPM practices and the ways how Plantwise has engaged with the key partners in the different countries where the program is being implemented, promoting the implementation of IPM approaches in order to improve agriculture systems, mainly those from subsistence agriculture, in Latin America.

Keywords: integrated pest management, Latin America, Plantwise, plant health systems

1. Introduction

One of the main challenges of the agriculture is to provide increasing supplies of food for a growing population with the increase in efficiency in the use of inputs and reduction of the environmental impacts from production [1], where both the ecological and economic dimensions are considered [2]. In this context, Yudulmen et al. [3] stated that the efficient management of insect pests should have a high priority given that insects still take about 15% of potential global crop yields [3]. However, the use of pesticides as one of the major control strategy adds economic and environmental costs to the food production equation [4].

The Integrated Control Concept (ICC) created by Stern [5] gave rise to the idea of the integrated pest management (IPM) and it has been a scientifically accepted "paradigm" for pest management worldwide for more than 50 years. In the context of the ICC, a fundamental element is to understand that any control system imposed on a given pest in a given crop has consequences for the management of other pests and crops in the ecosystem [6]. Thus, the IPM is a multitactic nature approach, including aspects related to host plant (such as plant nutrition, plant physiology, and plant resistance) and the economic aspects.

Considering the pyramidal conception of an IPM program designed for whitefly management (**Figure 1**), it is possible to generalize that model to other pests. In this regard, we could state that avoidance constitutes the basis of a pest management program, although some might reside on more than one level. For example, when facing a pest outbreak, decisions could be made based upon the upper two levels of the pyramid.

Later, Kogan [8] defined IPM as a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/

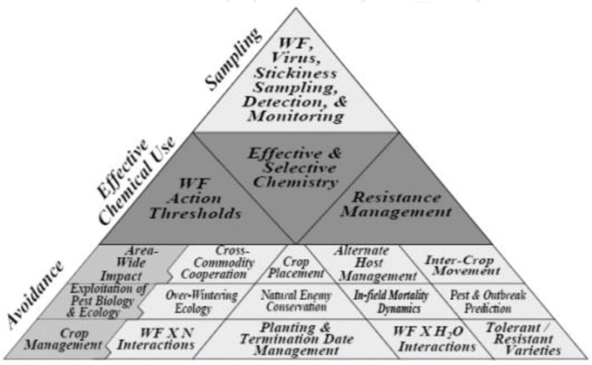

Figure 1. Conceptual diagram of whitefly IPM, depicting three keys to whitefly management (left): sampling, effective chemical use, and avoidance. Avoidance is subdivided among three interrelated areas: area-wide impact, exploitation of pest biology and ecology, and crop management (from: [7]).

benefit analyses that take into account the interests of and impacts on producers, society, and the environment. According to Rodríguez and Niemeyer [9], this definition inherently considers the existence of ecological and economic thresholds, the need to adopt the socioecosystem as a management unit, the existence of a broad number of IPM tools including the rational use of chemical pesticides, and the requirement for interdisciplinary systems approach, particularly since certain control measures may produce unexpected and undesirable effects. As complement to the classical definition, the United States Department of Agriculture has defined the IPM as a long-standing, science-based, decision-making process that identifies and reduces risks from pests and pest management–related strategies [10].

Additionally, Naranjo and Ellsworth [6] discussed the evolution of IPM concepts built on the original four components: thresholds for determining the need for control, sampling to determine critical densities, understanding and conserving the biological control capacity in the system, and the use of selective insecticides or selective application methods, when needed, to augment biological control.

2. Plant protection techniques used in IPM

IPM relies mainly on natural mortality factors such as natural enemies and weather seeking out tactics that disrupt these factors as little as possible [11]. In a broader sense, it includes all plant protection measures that help to prevent or manage pests, whether through general crop management practices such as rotation, or of cultural, physical, biological, or chemical nature. When pesticides are applied, two crucial items to be considered are determining when pesticides actually need to be used and the choice of chemicals should be made with consideration of compatibility with nonchemical methods (e.g., natural predators), pest population level, and resistance management, products' profiles. In an IPM context, these decisions are heavily based on an important step such as the biological monitoring (also referred as 'scouting'), which consists of sampling procedures designed to estimate the stages and population densities of both pests and beneficial organisms [12]. Unfortunately, biological monitoring is a very knowledge-intensive procedure and requires highly trained individuals to obtain reliable data and consequently ensure the success of the program. On the other hand, since both pest populations and the growth and development of crop plants are governed by environmental parameters, monitoring environmental conditions should be another core component of IPM [12].

For all that, crop production is dynamic; the decisions on pest management measures should be taken at farm level based on a wide variety of instruments, such as qualified advisers' recommendations, alert services and infestation forecast, research results, experience, and threshold values. However, the actual techniques to be included in an IPM approach on-farm will vary not only between crops but also within the same crop grown in different geographical locations, or between years, depending on pest pressure, weather patterns, crop rotation, and other factors, as well as availability of tools and resources [13]. All these should consider economic aspects, trying to allocate scarce resources (capital or labour) [14].

3. Biological control and IPM

Biological control has been a valuable tactic in pest management programs around the world for many years, but has undergone a resurgence in recent decades that parallels the development of IPM as an accepted practice for pest management [15]. Since natural enemies are often key factors in the dynamics of pests, biological control should be the cornerstone of IPM practices [16]. However, when implementing an integrated pest management programs, special care should be taken in what specific tactics could be used since they do not act independently of one another. This is especially true for biological control since the agents of insect biological control are susceptible to environmental factors, such as pesticides, cultural control, mechanical and physical control, and transgenic crops [15].

However, both biological control and IPM faced some obstacles originating from the lack of biological data and the lack of knowledge to develop economically, environmentally, and socially sound crops and animal production systems [17].

Insect or mite species	**Developmental stage attacked**	***Rhynchophorus* species**	**Location**
Insects			
Anisolabis maritime (Dermaptera: Anisolabididae)	Eggs, larvae and pupae	*R. ferrugineus*	Saudi Arabia
Chelisoches morio (Dermaptera: Chelisochidae)	Eggs and larvae	*R. ferrugineus*	India
Euborellia annulipes (Dermaptera: Anisolabididae)	Eggs	*R. ferrugineus*	Italy
Platymeris laevicollis (Hemiptera: Reduviidae)	Unknown	*R. ferrugineus*	Sri Lanka
Xylocorus galactinus (Hemiptera: Anthocoridae)	Eggs, larvae and pupae	*R. ferrugineus*	Saudi Arabia
Xanthopygus cognatus (Coleoptera: Staphylinidae)	Eggs and larvae	*R. palmarum*	Ecuador
Sarcophaga fuscicauda (Diptera: Sarcophagidae)	Adults	*R. ferrugineus*	India
Billea rhynchoporae (Diptera: Tachinidae)	Pupae	*R. palmarum*	Brazil
B. maritima	Pupae	*R. ferrugineus*	Italy
B. menezesi	Pupae	*R. palmarum*	Brazil
Megaselia scalaris (Diptera: Phoridae)	Pupae	*R. ferrugineus*	Italy
Scolia erratica	Larvae	*R. ferrugineus*	Malaysia

Insect or mite species	Developmental stage attacked	*Rhynchophorus* species	Location
(Hymenoptera: Scolidae)			
Mites			
Aegyptus alhassa (Mesostigmata: Trachyuro podidae)	Eggs, pupae and adults	*R. ferrugineus*	Saudi Arabia
A. rynchophorus	Pupae and adults	*R. ferrugineus*	Egypt
A. zaheri	Pupae and adults	*R. ferrugineus*	Egypt
Uroobovella marginata (Mesostigmata: Urodinychidae)	Pupae and adults	*R. ferrugineus*	Egypt
Hypoaspis sardoa (Mesostigmata: Laelapidae)	All stages	*R. ferrugineus*	Egypt
Hypoaspis sp.	Adults	*R. ferrugineus*	India
Iphidosoma sp. (Mesostigmata: Parasitidae)	All stages	*R. ferrugineus*	Egypt
Parasitis zaheri (Mesostigmata: Parasitidae)	Larvae and pupae	*R. ferrugineus*	Egypt
Rhynchopolipus rhynchophori	Larvae	*R. ferrugineus*	India
(Prostigmata: Podapolipidae)	Adults	*R. palmarum*	Central and South America, Costa Rica
R. brachycephalus	Adults	*R. phoenicis*	Cameroon
R. swiftae	Adults	*R. ferrugineus*	Indonesia, Malaysia, Philippines

Table 1. List of insects and mites as natural enemies of *Rhynchophorus* spp. worldwide (from Mazza et al. [19])

The red palm weevil, *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae), is a well-known problem for the damage it causes to coconuts (*Cocos nucifera*) grown in plantations so that much research has been conducted with a strong emphasis on the development of IPM based on pheromone traps and biological control rather than insecticides [18]. Thus, these authors stated that the prospects for the development of a biological control component for an integrated management strategy are good; however, the establishment and effectiveness of the biological control may depend on the intensity of management practices in palm (*Phoenix dactylifera*) plantations. In addition, there is also scope for the development of biopesticides to replace directly or to reduce the use of chemical pesticides. In this regard, Mazza et al. [19] have showed a list of insects and mites as natural enemies of *R. ferrugineus* worldwide (**Table 1**). As shown, most diverse insect groups belong to Diptera (4 spp.) and Dermaptera (3 spp.), while in the group of mites, Mesostigmata are the dominant species group. Regarding geographical distribution, most of the studies have been conducted in Egypt and in some countries from Asia (India, Indonesia, Malaysia, Philippines, Saudi Arabia, Sri Lanka) and most discrete number of studies in Latin America, with reports from Brazil, Costa Rica, and

Ecuador. This fact reveals the limited information about natural enemies in Latin America, thus making difficult to establish IPM programs with a predictable success opportunity. Thus, more studies concerning the biological parameters of the pests and their natural enemies are required in this geographical area.

Another successfully pest control program, known as the Moscamed Program, was developed in Mexico with participation of Mexican and Guatemalan authorities and the USDA in collaboration with the FAO and International Atomic Energy Authority (IAEA) to manage the Mediterranean fruit fly (*Ceratitis capitata*). The Moscamed program involved the application of insecticidal baits, mechanical and cultural control of hosts, restrictions on the movement of fruits and vegetables and the release of sterile males produced in the Moscamed plant at Metapa, Chiapas [20].

4. IPM in some Latin American countries: successful experiences

In South America, IPM has been successfully implemented in Argentina [lucerne (*Medicago sativa*), citrus (*Citrus* sp.), soybean (*Glycine max*)], Brazil [(citrus (*Citrus* sp.), cotton (*Gossypium* sp.), soybean (*G. max*), sugarcane (*Saccharum officinarum*), tomato (*Solanum lycopersicum*), wheat (*Triticum vulgare*) and livestock)], Chile [wheat (*Triticum vulgare*)], Colombia [cotton (*Gossypium* sp.), ornamental (*Rosa* sp.), soybean (*G. max*), sugarcane (*Saccharum officinarum*), tomato (*Solanum lycopersicum*)], Paraguay [cotton (*Gossypium* sp.), soybean (*G. max*)], Peru [cotton (*Gossypium* sp.), sugarcane (*Saccharum officinarum*)], and Venezuela [cotton (*Gossypium* sp.), sugarcane (*Saccharum officinarum*)] [20].

4.1. Argentina

Since the 1970s, Argentinian public institutions started to introduce farmers to IPM strategies by implementing a program of Extension and Technology Transfer focusing on the rational use of pesticides [21]. Although other IPM programs in soybeans, potatoes, and orchard crops have been developed, the cotton IPM program is being the oldest program. In this cotton IPM program, some strategies such as conservation of natural enemies, prevention of pesticide resistance, and cultural practices have been used.

At the beginning of the IPM program, farmers and technicians were trained for insect identification and monitoring training, however, few growers put the knowledge into practice. As a consequence of the severe economic problems caused by the lack of control of *Alabama argillacea* (leafworm) in cotton (*Gossypium* sp.), a new technology transfer program was organized to teach IPM philosophy and thus the Cotton IPM Program reappeared [21]. According to these authors, after this fact, farmers understood that adequate insecticide use at the proper timing and at the correct dose reduces costs of production and provides more efficient crop management.

4.2. Brazil

Pesticide resistance, pest resurgence, worker poisoning, and ecological imbalances became apparent after indiscriminate pesticide usage in Brazil. In this regard, research was carried out on sampling methods on pests and natural enemies, use of threshold levels, and the correct timing for insecticide application [22]. Consequently, highly successful IPM programs were developed for several crops, including sugarcane, tomato, wheat, and soybean [23].

According to Hoffmann-Campo [23], most IPM programs in Brazil are characterized as follows:

a. IPM is strongly based on using on the production and release of biological control agents with new IPM programs being developed making an emphasis on conservation and augmentative biological control, cultural practices, and host plant resistance and emphasize the reduction of broad-spectrum insecticide use.

b. Considerable improvements are expected in the methods of production and release of indigenous entomopathogens, parasitoids, and predators. Some systems are exploring classical biological control.

c. Brazilian farmers are increasingly using safer and more selective insecticides, such as the biological, the insect growth regulators (IGRs) and nicotinoids and other new products released by private companies. IPM tactics are increasingly used in Brazil since more high-quality food and fewer chemical pesticides used in food production are currently demanded by consumers and also due to the policies for registration and use of insecticides in the country have become more stringent.

d. Organic farms are a growing sector in Brazil, with an increasing demand for pest control methods that can be used on organic crops.

e. Although continuous development and improvement of IPM programs in Brazil is important, improved technology transfer and outreach to growers is fundamental. After introduction of the Genetically Modified Organisms (GMOs), research on their application to IPM programs is underway, especially their impact on natural enemies, nontarget insects, and other arthropods that feed on these crops, as well as the possibility of pest resistance.

IPM tactics must be made widely available to farmers through research institutions, official and private (farmer's cooperatives) extension services, and private companies. It is only by educating farmers on the importance and benefits of using IPM tactics for pest control that IPM programs can have a broader impact on agriculture in Latin America.

4.3. Ecuador

Information about IPM in Ecuador is still scarce. However, some attempts have been done mostly in cocoa (*Theobroma cacao*), sugar cane (*Saccharum officinarum*), and vegetable crops. In Ecuador, about 500,000 ha are planted with cocoa cultivars 'CCN-51' and 'Nacional'. Defoliating insects belonging to Saturdinae and Megalopygidae (Order: Lepidoptera) commonly infest these cultivars. When high population levels are attained in adult plantations, control by broad-spectrum insecticides application is limited since populations of pollinators can be affected. Foliage application of biological pesticide *Bacillus thuringiensis* (New BT 2X at a rate 0.5 kg ha^{-1} or New BT 8L at 1 L ha^{-1}) has showed promissory results in control of these lepidopteran pests [24].

Sugar cane: Program for the development of IPM from CINCAE (Centro de Investigación de la Caña de Azúcar del Ecuador) has proposed the following program [25]:

a. During the first phase, an evaluation and characterization of pests to determine the impact (population, damage, and grower's perception), followed by bioecological studies (life cycle, behavior, and population dynamic).

b. After that, some management components should be developed, focusing in methods of control that provoke more permanent natural mortality, being pesticides the last strategy to be considered. When pesticides are used, the minimum number of applications of selective molecules should be considered. After that, key components are integrated in a basis ecological, agronomical, and socioeconomically compatible.

Finally, pilot units are settling down in fields where these compatible components are used according to the characteristics of each agroecosystem.

4.4. Mexico

Mexico has a long history of proactive pest management, and more recently, IPM has become even more important as trade regulations that have begun to restrict the amounts of pesticide residue or insects that may be present on produce exported to the USA and Canada [26]. In order to maintain the extensive trade in fresh fruits and vegetables, these commodities must comply with strict regulations that are difficult to meet with conventional pest control methods, being IPM, in most of the cases, the only viable option for growers intending to export their products [26]. Several IPM programs have been successfully developed in Mexico.

IPM to control the tomato pinworm, *Keiferia lycopersicella* and other lepidopteran species in tomato has included careful scouting (primarily with pheromone traps from planting to harvesting), cultural control (including plowing under crop residues promptly after harvesting, cleaning drainage ditches and irrigation canals where alternate hosts grow, and establishing a tomato-free period during summer or winter to break the cycle of tomato pinworm reproduction), mating disruption, use of selective insecticides, and biological control [23].

The parasitoid wasp, *Trichogramma pretiosum* is an egg parasitoid of tomato pinworm and it has been found occurring in several Mexican states (Chihuahua, Coahuila, Durango, Nuevo León, Sinaloa, Sonora, Tamaulipas, and Zacatecas) [27]. This parasitoid species has been released in combination with mating disruption [28]. Due to the overuse of insecticide applications, the tomato pinworm has developed resistance to conventional insecticides so that combined use of pheromones, biological control, and selective insecticides has reduced damage and number of insecticide applications [23].

IPM in cruciferous [the diamondback moth, *Plutella xylostella*]: effective cultural control methods included plowing to eliminate crop residue, and rotation with nonhost crops, careful inspection of nursery plants for diamondback moth eggs and larvae helped to prevent accidental introduction of diamondback moth into the field [29]. In addition, biological control has showed to have an important impact on the control of the diamondback moth, including use of native parasitoid species and the introduction of effective exotic species. In Puebla, a last-instar-parasitoid of diamondback moth, *Diadegma insulare*, has been found parasitizing 46.7% of *Plutella xylostella* larvae in cauliflower [30].

IPM of fruit flies [*Ceratitis capitata*]: according to Mota-Sánchez et al. [26], success of IPM of fruit flies relies on the following crucial steps:

a. Early detection and identification.

b. Reduction of the population by using cultural control, application of selective baits: adult fruit flies are monitored using glass McPhail traps [31] baited with hydrolyzed protein at a density of one to five traps per hectare depending on the species. Fruit sampling is complementary to the trapping and is useful for the detection of larvae. Fruit sampling starts as soon as the orchards and areas outside of the orchards (fruit trees in yards of houses or other hosts in noncommercial areas) have fruits big enough to be infested by fruit flies.

c. Production and release of parasitoids and sterile fruit flies.

d. Strict limitations on fruit movement out of infested areas.

Apart from the strategies for pest control, some other aspects have contributed to the success of IPM programs in Mexico (**Figure 2**).

Figure 2. Factors contributing to the success of IPM in Mexico.

However, Mexico still face challenges as some poor farmers cannot afford to implement IPM. Mexico is a country of contrasts where 50 million people live in poverty including poor farmers. Some government programs have been dedicated to improve the conditions of poor people in the country, however, is not an easy problem to solve.

4.5. Colombia

In Colombia, the production of passion fruit (*Passiflora* spp.) is mainly in hands of small farmers. Being cultivated over 8000 hectares, *Dasiops inedulis* (Díptera: Lonchaeidae) is a key pest of passion fruit crop, but there is little information regarding their biology, ecology, and management. Local producers have large production losses due to pests, due to limited knowledge to manage them properly, facing difficulty in positioning their products in the market.

In 2008, Centro Internacional de Agricultura Tropical (CIAT) researchers worked together with local universities and farmer associations to develop a sustainable pest management package for *Dasiops inedulis*. This work allowed farmers to increase their IPM package at the field level. Field surveys conducted from 2008 to 2010 in the main fruit producing regions provided information about the pest population dynamics and geographic patterns of infestation [32]. Then, a national survey of farmers was conducted to get an idea of agroecological behavior management and local knowledge of the farmers. Apart from the common use of insecticide applications based on the calendar of application, they experimented extensively with the farmers the use of inexpensive bait traps. By using participatory practices in five agricultural communities, the farmers realized that some of the new management practices were much more effective and less expensive than current practices of pesticide application [33].

4.6. Peru

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 [34]. In 1971, graduate programs (MSc level) in entomology and plant pathology were initiated at the National Agrarian University 'La Molina'. 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 Modules of Technical Assistance, coordinated by INIA (Instituto Nacional de Innovación Agraria) at the national level, which have the plant clinics as the diagnostic component, PRONAMACHCS (Programa Nacional de Manejo de Cuencas Hidrográficas y Conservación de Suelos; it is a national program for the management of soils and watersheds), and SENASA (Servicio Nacional de Sanidad Agraria; it is the national service for plant and animal health) [34].

In Peru, most of the vegetable species are usually cultivated in smallholder farms; hence, agricultural production is characterized by lower productivity due to limited availability of good quality seeds and pest problems, besides lack of selected varieties adapted to the agroecosystem [35]. Moreover, most of the farmers do not recognize neither pest species nor beneficial organisms, making insecticide/fungicide applications when is not necessary [35].

All these factors highlight the need to establish an education program for farmers to be trained in sustainable pest management. Saldaña et al. [36] proposed an IPM program for industrialized tomato to manage populations of the two most important pests (*Tuta absoluta* and *Bemisia* spp.) in Barranca, Lima (**Figure 3**). This proposal was based on the pest evaluation strategy, action thresholds, and the application of different control methods, including the establishment of planting dates (legal control), optimization of farming practices (cultural control), installation of light and pheromone traps (ethological control), and removal of virosic plants (mechanical control), maintenance of natural enemies populations (biological control), and selective application of pesticides (chemical control).

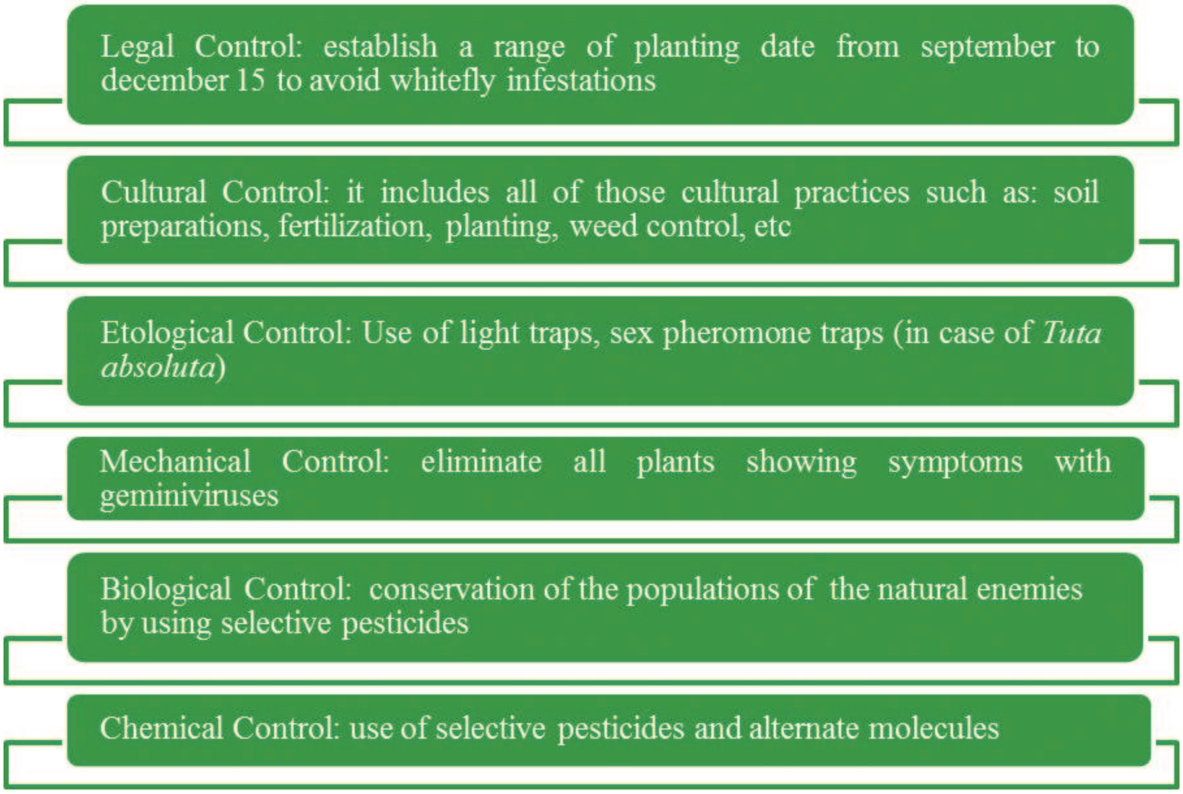

Figure 3. IPM program proposed for pest control in industrialized tomato in Peru (from: [36]).

As a first step, authors developed a methodology to evaluate the specific characteristics of the agricultural ecosystem to determine pest incidence on different phenological stages and establish thresholds to take more efficient control measures. The pest evaluation methodology developed by Sarmiento and Sánchez [37], consists in considering 5 ha as a unit of evaluation which is divided into five subunits. In each subunit, five plants are sampled (four shoots, one leaflet from basal and middle strata, four inflorescences, one twig, and four fruits along 2 m in a furrow).

5. IPM in Latin America: status and challenges

As stated by Rodríguez and Niemeyer [9], IPM research and promotion have responded, in one hand, to food security, which is devoted to the protection of a subsistence crop mainly focused on smallholder peasants, and on the other hand, exports which try to fulfil the requirements of foreign markets and are concentrated in larger producers.

Although research and field-level implementation of IPM has been most successful in the United States and Europe, IPM has made significant progress in developing countries, but focused generally on large-scale rather than small, subsistence farms [38]. According to Rodríguez and Niemeyer [9], government programs and subsidies in developing countries have been concentrated on medium and large farmers since they are able to hire personnel to develop research or to create links with external institutions. Thus, in some countries, such as Chile, there are grant funds available for agricultural research and innovation projects incorporating IPM practices involving partnerships with private firms under a commitment to transfer the results to potential users. Given the requirements for partnerships, the program is not easily available for small farmers, and most research is guided by the specific needs of larger export companies. However, increasingly, scientists, policy makers, and donor agencies in developing countries are turning their attention to small farmers.

Some farmers have benefited greatly from introduced technologies in major production areas in Latin America as many of the new crop technologies have increased crop yield and also their commodity crops can be sent to market [39]. Conversely, those farmers poorly served by markets or have not been reached by modernization packages, the technologies, and practices have failed to generate significant benefits in crop protection systems [40].

The media and public agricultural extension have played a crucial role in introducing the new technologies and good agricultural practices to farmers, however; there has been little investment in farmer education so that they are able to expand their capabilities to understand, innovate, and adapt to the changing context [39]. Although more effort to expand farmers' capabilities to improve production and productivity have been made, agricultural development programs have been unsuccessful because they failed to educate farmers on the sustainable management of variable agroecosystems and to cope with the changes in marketing demands arising from globalizing food and commodity trade [39, 41].

As stated by van den Berg and Jiggins [39], the role of the new generations of farmers has reduced to be simple technology clients, leading them to lose much of the indigenous agricultural knowledge and skills, and in the integrity of the social organization in which indigenous innovation capacity is embedded.

Thereby, the challenge then would be focused to capacitate the millions of small farmers to deal with pest and become experts in decentralized pest management through practical, field-based learning methods.

6. Plantwise helping small farmers to produce in a sustainable way

In some areas, up to 70% of food is lost before it can be consumed. This problem is exacerbated by international trade, intensified production, and climate change altering and accelerating the spread of plant pests. Clearly there is an opportunity to lose less and feed more by improving control of such pest problems, particularly in the developing world [42, 43].

Plantwise (www.plantwise.org), an innovative global program, led by CABI, aims to contribute to increased food security, alleviated poverty, and improved livelihoods by enabling male and female farmers around the world to lose less, produce more, and improve the quality of their crops. Working in close partnership with relevant actors, Plantwise strengthens national plant health systems from within, enabling countries to provide farmers with the knowledge they need to lose less and feed more [44].

The Plantwise approach is based on three interlinked components:

1. An evergrowing network of locally-run **plant clinics**, where farmers can find advice to manage and prevent crop problems. Agricultural advisory staff is trained to identify any problem on any crop brought to the clinics, and provide appropriate recommendations guided by national and international best practice standards.

2. Improved information flows between everyone whose work supports farmers (e.g., extension, research, input suppliers, and regulators). Collaboration within national **plant health systems** enables these actors to be more effective in their work to improve plant health, with concrete benefits for farmers.

3. The Plantwise **knowledge bank**, a database with online and offline resources for pest diagnostic and advisory services, provides both locally relevant, comprehensive plant health information for everyone and a platform for collaboration and information sharing between plant health stakeholders.

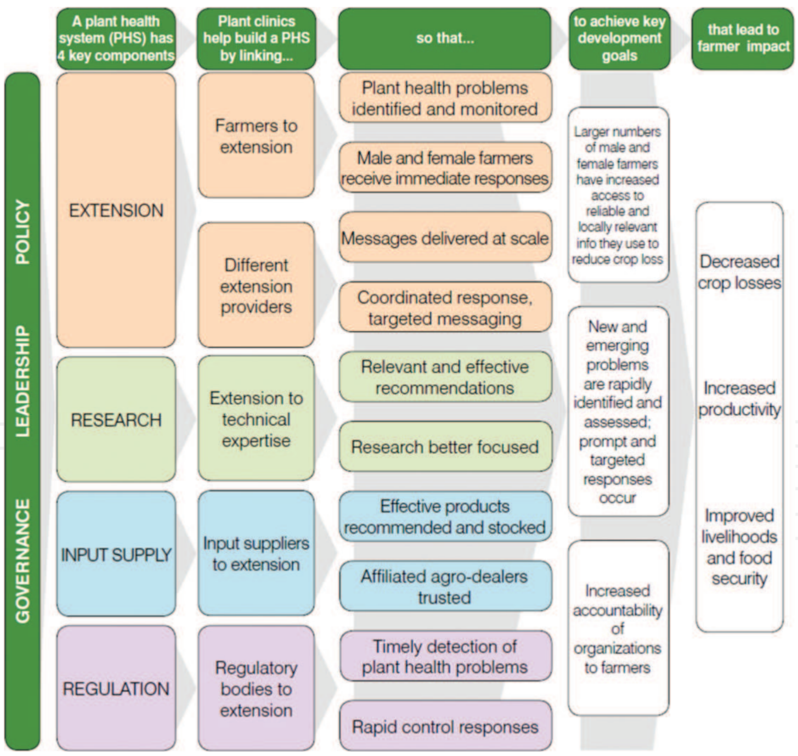

Figure 4. Plantwise theory of change (from: [46]).

In the Plantwise knowledge bank, plant clinic records are collated and analysed to support the quality of advice given to farmers and inform decision-making. By putting knowledge into the hands of smallholder farmers, Plantwise is able not only to help them lose less and feed more but also to gather data which can assist all stakeholders in the plant health system-from research, agro-input supply, extension and policy-making. Most importantly, Plantwise is a development program which cooperates with a number of international and national organizations working to remove constraints to agricultural productivity. Countries are now using plant clinics and Knowledge bank resources to improve national vigilance against pest outbreaks [45].

The key premise of the Plantwise Theory of Change is that plant health systems function to reduce crop losses and promote plant health (**Figure 4**). Plantwise defines a plant health system by four key components: (1) extension, which delivers available knowledge intended to improve plant health; (2) research, which develops new knowledge about plant health and is often linked to higher level education; (3) input suppliers, who deliver knowledge and physical inputs such as seeds, biological and other crop protection products, and fertilizers; and (4) regulation, which regulates sale and use of agricultural inputs, protects countries from new and emerging pests (invasive species included), and regulates produce export requirements.

The Plantwise approach develops sustainable mechanisms to deliver better plant health services that address farmer needs and improve output, including (1) improving advisory services based on plant clinics and complementary extension approaches and delivering effective responses to any plant health problem affecting any crop; (2) improving regulatory systems so that plant health problems are detected early and advisory staff on the ground are able to communicate appropriate mitigation measures to farmers before the problems become devastating; (3) stimulating research that supports farmers' needs; and (4) improving input supply ensuring provision of appropriate, legitimate, and effective goods [46].

The Plantwise programme encourages extension officers to offer plant health management advice to farmers guided by the principles of integrated pest management (IPM), looking forward to increase the sustainability of the production system [46].

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