Building Bridges between Disciplines for Sustainable Crop Protection

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Abstract

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Plant protection is an interdisciplinary area that historically involved agronomy, plant breeding, entomology, plant pathology, statistics, and weed science. After World War II, pesticide development took precedence and chemistry, physics, and engineering were favored. This led to excessive use of synthetic pesticides, causing pest resistance to insecticides, contamination of ecosystems and undesirable health effects. As a result, the integrated pest management concept was developed in the 1960s. This expanded into new disciplines, such as mathematics, computer science, meteorology, and aeronautics to forecast pest occurrence and dispersal. It also included molecular biology and microbiology to produce biological control agents and GMOs and to manage pest resistance in them. IPM can contribute to sustainable agriculture both philosophically and functionally. IPM and sustainable development evolved during the last three decades of the 20^{th} century. This process was supported by the integration of several basic and applied sciences in the development of plant protection components and dissemination of information. These include the social sciences such as economics, sociology, and gender studies. Also, public and private institutions are involved in the research and development of plant protection technologies, production and distribution, implementation, adoption, and evaluation in the field.

Introduction

Since the prehistoric times, at the advent of agriculture, humans, crops, and pests co-existed. Slowly, humans tried to reduce the share of food that crop pests consumed by introducing early pest control techniques such as application of sand, lime, ash and other inert products. Eventually pest control progressed to the use of plant products, predatory insects like ants, cultural practices and chemicals. The discovery of DDT in the 1940s has drastically changed pest control methods. This led to the development and use of several residual and highly toxic pesticides resulting in resistance development in pests, environmental degradation and public health hazards. Additionally, recommendations of the Green Revolution and their adoption of high input and high yielding varieties and excessive use of fertilizers and pesticides aggravated the situation. In spite of the progress made in the development of integrated crop management strategies there is currently a world food crisis

Global Food Security

The World Food Summit of 1966 defined “food security” as existing “when all people at all times have access to sufficient, safe, and nutritious food to maintain a healthy and active life.” Food insecurity is part of a continuum that includes hunger (food deprivation), malnutrition (deficiencies, imbalances, or excess of nutrients) and famine. Although difficult to measure, food security statistics indicate that there is a food crisis in a stressed world. Consider the facts that 805 million people suffer from malnutrition; Most of the 805 million are in Southern Asia (35%), sub-Saharan Africa (27%), and Eastern Asia (19%); 99% of the undernourished live in developing countries; 642 million people in Asia and the Pacific are undernourished; 6 million children's deaths/year are linked to malnutrition (3).

The world faces three major challenges: 1) to match the rapidly changing demand for food, 2) to do so in ways that are environmentally and socially acceptable, and 3) to ensure that the world's poorest people are no longer hungry. Crop yields have fallen in many areas due to declining investments in research, increasing water scarcity, land degradation, climate change, and biotic and abiotic stresses (insect pests, plant pathogens, nematodes, weeds, vertebrates, drought, flooding, extremes of temperature and nutrient deficiency). Globally, an average of 35% of crop yields are lost to pre-harvest pests and 10-20% to post-harvest pests. Overall, weeds cause the highest potential losses (32%), with animal pests and pathogens being less important (losses of 18% and 16% respectively). Invasive species, climate change, and the loss of biodiversity due to the misuse of pesticides amongst other factors all contribute to increased pest-induced losses (3).

World population is expected to reach nine billion in 2050. To feed this population, there must be a 60–70% increase in food production. We must also figure out a way to deal with the effects of climate change. The area under cultivation is not expected to expand to meet the gap, and we have yet to meet it by increasing yield per unit area and reducing losses in field and post-harvest handling. A concerted effort to reduce these losses without jeopardizing environmental and public health concerns by adopting Integrated Pest Management (IPM) could reduce the loss by

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50%, leading to a needed increase in food production of only 30% (3).

IPM and Multidisciplinary

In the 1960s, early in the development of the IPM approach to pest control, a group of entomologists at the University of California recognized the perils of the use of highly toxic and residual pesticides and recommended the adoption of Integrated Pest Management (IPM). Their idea was supported by the publication of 'Silent Spring' by Rachel Carson in 1962 (1), leading to financial support from USAID, FAO and other organizations to implement IPM programs.

The term 'Integrated Pest Management' has several definitions but in general, they all mean integration of all available technologies for control of pests and diseases that are economical, environmentally safe, socially acceptable and less hazardous to health.

One of the organizations that has been concentrating on non-chemical methods of crop protection is the Farnham House Laboratories for Biological Control in England and later it became Commonwealth Institute of Biological Control.

Until the 1950s, crop protection was mostly addressed by entomologists and plant pathologists. In the 1960s, the work of Painter led to the development of insect resistant varieties, by plant breeders, and their integration into a pest management package. Meanwhile, areas such as microbial control, pesticide regulations, pest resistance management, male annihilation technique, pheromones, GMOs and others were developed and integrated.

Recognizing the importance of IPM, the USAID supported IPM projects at Oregon State University in the 1960s, University of California in the 1970s, Consortium for International Crop Protection in the 1970s and 1980s and the Integrated Pest Management Collaborative Research Support Program (now, Feed the Future Integrated Pest Management Innovation Lab) since 1993 onwards.

Currently most research that support crop protection is involved in multidisciplinary areas. The setup of the IPM Innovation Lab provides an example of how various disciplines are integrated to develop and implement IPM packages for various crops.

In the past, the IPM Innovation Lab (IPM IL) worked in 20 or more developing countries, but in the current phase, it is involved in four countries (Bangladesh, Cambodia, Nepal and Vietnam) in Asia and three countries (Ethiopia, Kenya, and Tanzania) in Africa, where it develops and implements IPM packages for vegetable, fruit, cereal, and legume crops (8, 9).

IPM Packages are an important component for controlling pests and increasing food production. The packages are holistic suites that include recommendations for the production of vegetables and other crops in tropical countries. An IPM package consists of various technologies to manage the economically important pest species of different crops from the time of soil preparation to harvest. Farmers who use IPM packages in planting, production, and harvest see enhanced profitability in their crops. The IPM Innovation Lab has created packages for eggplant, cucurbits, tomato, beans, cabbage, cauliflower (6) onion (2), and okra (7).

Networking among Disciplines in the Current IPM IL Projects

There are eight projects in the current IPM IL portfolio and their focus and involvement of scientific disciplines differ according to the needs of the program, region and country. Strong networks are a basic element in the IPM IL Participatory IPM (PIPM) approach. PIPM involves as many stakeholders as possible and a mechanism that provides for that participation is networking (4). Collaboration among disciplines in the eight IPM IL projects is presented.

1. IPM for dragon fruit, longan, lychee, and mango in Vietnam- Disciplines involved in this project are entomology, plant pathology, horticulture, extension, gender, microbiology, molecular biology, taxonomy, physics (irradiation and hot vapor treatment), chemistry, engineering, gender, and business management.
2. IPM for rice in Cambodia- In this project, entomology, zoology, plant pathology, virology, nematology, engineering (drones), economics, sociology, weed science, and extension are involved.
3. IPM for vegetable crops in Bangladesh, Cambodia, and Nepal- Participating disciplines are entomology, plant pathology, virology, economics, gender, sociology, agronomy, horticulture, business management, molecular biology and extension.
4. Climate change and biodiversity in Nepal- Modeling, remote sensing, botany, entomology, sociology, agronomy, horticulture, ecology.
5. Modeling invasive species- This project includes scientists specialized in computer science, modeling, entomology, ecology, taxonomy, molecular biology, economics, and meteorology.
6. Biological control of the weed, *Parthenium* in East Africa- Weed science, entomology, plant pathology, sociology, economics, gender, ecology, agronomy, modeling and animal science.
7. IPM for vegetables in Ethiopia, Kenya and Tanzania- Horticulture, weed science, entomology, plant pathology, sociology, economics, and extension.
8. IPM for rice, maize, and chickpea in Ethiopia, Kenya and Tanzania- Specialists in entomology, plant pathology, gender, economics, communications, extension, agronomy, and sociology.

It is safe to state that different scientific disciplines are bridged to varying degrees, in the current crop protection programs as based on the needs to manage pests and diseases in an economically, socially and environmentally acceptable manner. The result of collaboration among disciplines and networking amongst all stakeholders has resulted in projects that that have had a significant impact on promoting food security in Asia and Africa. Two case studies are presented.

Successful IPM IL Case Projects

IPM Innovation Lab Beyond its Boundaries (5)
Although the IPM Innovation Lab has projects in only seven countries, its work extends far beyond these borders through a strong network of stakeholders. The program holds workshops, meetings, and symposia that draw attendees from almost every continent and participates in international conferences on entomology and plant pathology.

In August 2015, the IPM Innovation Lab organized a symposium on the South American tomato leafminer, *Tuta absoluta*, at the International Congress of Plant Protection, Berlin, Germany and formed a working group of the International Association for Plant Protection Sciences. Participants from sixteen countries attended this symposium.

Another *Tuta absoluta* symposium was organized at the Fourth International Conference of Eco-friendly Applied Biological Control of Agricultural Pests and Phytopathogens at the Arab Society for Plant Protection (ASPP) (http://www.asplantprotection.org/) in Cairo, Egypt in October of that same year. Then in November, the IPM Innovation Lab organized a symposium on IPM programs in Asia and Africa at the annual meeting of the Entomological Society of America.

At the International Congress of Entomology in Orlando, Florida in September of 2016, the IPM Innovation Lab organized two symposia and had an information booth for the over 7000 conference participants. In the symposium on Integrated Pest Management Components and Packages for Tropical Crops, there were presentations from CGIAR centers, the FAO, land grant universities, and developing country institutions covering IPM components and packages developed for vegetable, cereal, and fruit crops. In the symposium on *Tuta absoluta*, there were presentations from the USDA, USAID, and representatives from countries in Asia, Africa, and Europe. It covered biology, spread, monitoring, and management of this insect and drew over 60 attendees.

A symposium on *Tuta absoluta* and a symposium on Biological Control of Invasive Species was organized at the International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood, Kathmandu, Nepal in January of 2017. The conference had over 300 attendees from countries around the world, including the president of Nepal.

By organizing symposia on IPM topics, the program is able to take the IPM technologies developed for tropical crops far beyond the USAID designated host countries of the IPM Innovation Lab. Even though the IPM Innovation Lab has been authorized to work in four countries in Asia and three countries in Africa, because of dissemination of information through these international meetings, congresses, and conferences, the message of IPM is spread throughout the world

The IPM Innovation Lab: Promoting Biological Control in Cambodia (5)
Microbial bio-pesticides are used in the biological control of insect pests, plant pathogens, and weeds. *Trichoderma* is an inexpensive, environmentally friendly bio-agent used by the USAID-funded IPM IL to reduce farmers' need for expensive chemical fungicides. *Trichoderma* species are beneficial plant symbionts that act as natural bio-control agents against several important phytopathogenic fungi. *Trichoderma* can be used to combat soil borne plant pathogens (*Fusarium, Rhizoctonia, Phytophthora, Sclerotinia*, and *Alternaria*).

The IPM Innovation Lab has globally promoted the use of the 'fighting fungus'. The beneficial fungi, *Trichoderma* spp., which are present in most soils, have evolved numerous mechanisms for both to attack of plant damaging fungi and for enhancing plant and root growth.

For developing countries, where crop pests and diseases are a major problem and pesticides expensive, *Trichoderma* is a vital biological control agent and an alternate to environmentally harmful fungicides in an integrated approach to pest management. Nevertheless, not all farmers, scientists, and policymakers know it exists, know its benefits, how to obtain it or how to use it.

To help spread awareness, the IPM Innovation Lab has conducted six *Trichoderma* workshops in Asia and Africa. The purpose of the workshops is to inform stakeholders about the effectiveness of *Trichoderma* in a pest management program, to encourage participants to disseminate information to politicians and farmers on the beneficial aspects of the fungus and to encourage participant entrepreneurs to get involved in the local production of *Trichoderma*.

The latest of the series of six workshops was held at the Royal University of Agriculture in Cambodia. The 40 Cambodia workshop participants learned how *Trichoderma* controls plant pathogenic fungi, how to identify it, how to turn its production into a business, and how to incorporate its important disease-fighting benefits into their agricultural practices.

"Most farmers everywhere go for intensive cultivation of crops," said S. Nakkeeran, a plant pathologist from Tamil Nadu Agricultural University in India who led the workshop. "But intensive cultivation leads to indiscriminate application of pesticides, which end up as residues on food. We consume these pesticides. *Trichoderma*, which is a biocontrol agent, can be used for pest management instead."

The workshop was attended by Kean Sophea, a Cambodian scientist with the General Directorate of Agriculture and an entrepreneur who had previously attended an IPM Innovation Lab-run *Trichoderma* workshop in Nepal in 2014. Based on his attendance in the Nepal workshop, he developed his own small business producing the fungus. Other participants discussed their plans to take similar steps to make *Trichoderma* widely available throughout Cambodia.

However, there are constraints restricting the use *Trichoderma* in Cambodia: A shortage of the product and the absence of a registration system to regulate the quality and importation of *Trichoderma* formulations. To solve these problems, the IPM IL has networked with the scientists in the General Directorate of Agriculture, Director of Rice Crops Department, GIZ, ASEAN Sustainable Agrifood Systems (ASEAN SAS), and USAID in getting the government to legislate a registry allowing the import of Biological Control Agents (BCASs) including *Trichoderma*. Success of this networking activity resulted in an article in the Khmer Times.

In December 2017 Cambodia announced that it had just launched a new registry for companies that wish to import biological control agents (BCAs), effectively allowing the importation of these organisms which are widely used in other countries for pest control. Speaking at a workshop on the subject, Phum Ra, the director of the department of agricultural legislation at the Ministry of Agriculture, said his ministry has officially opened a registry for companies who want to import BCAs. He hailed this move as a milestone for the agricultural sector as it will reduce dependency of chemical products and widen producers' markets abroad. "BCAs will help farmers reduce their use of chemical pesticides and will boost crop yields."

Mao Canady, the manager of Eco-Agri Co, Ltd, welcomed the new registry. She said she had never imported these products before because of a lack of regulation, but said her company was already producing *Trichoderma* at their facilities to distribute locally. "We are happy with the government's decision. It will build trust for farmers, the private sector and consumers", Ms Canady said, adding that BCAs are generally cheaper than chemical pesticides and have a much smaller footprint on the soil and the environment.

Conclusion

The PIPM approach means 'learning from others' and is based on the cooperation and participation of all stakeholders: farmers, scientists, technology transfer specialists, policy makers, private industry and others. Success of a participatory approach involves networking and is determined in part to which it is able to link three key activities, 1) Problem identification, 2) Research and 3) Communication, extension and training activities. Strong networks are a basic element in a successful PIPM approach. Participatory IPM involves as many stakeholders as possible and a mechanism that provides for that participation is networking. This approach has been key in the success of the IPM IL programs. The IPM IL partners have played a key role, and success would not have been possible with only one agency involved (4).

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الملخص

مونيبابان، ر. و إي. أ. هاينريكس. 2018. أهمية بناء الجسور بين العلوم المختلفة لتحقيق إدارة مستدامة للمحاصيل الزراعية. مجلة وقاية النبات العربية، 36(1): 32–36.

تضم وقاية النبات العديد من الإختصاصات، وتاريخياً شملت علوم المحاصيل، تربية النبات، الحشرات، الأمراض، الأعشاب الضارة، والإحصاء. إزدادت أهمية تطوير المبيدات الكيميائية بعد الحرب العالمية الثانية، وبالتالي ازداد الإهتمام بعلوم الكيمياء والفيزياء والهندسة الصناعية، وأدى هذا التوجه المستجد إلإستخدام الزائد للمبدات الكيميائية المصنعة، وبالتالي ظهور صفة مقاومة الآفات للمبيدات مع تلوث للبيئة وما صاحب ذلك من أثر سلبي في صحة الإنسان. فرضت هذه التغيرات ظهور مبدأ المكافحة المتكاملة للآفات خلال الستينات من القرن الماضي، مما استوجب زيادة الإعتماد على علوم أخرى مثل الرياضيات، الحاسوب وعلوم الأرصاد والطيران للتنبؤعن وجود الآفات وانتشارها. وانضمت مؤخراً علوم البيولوجيا الجزيئية والميكروبيولوجيا لتطوير أدوات مكافحة بيولوجية وكائنات معدلة وراثياً لاستخدامها في إدارة مقاومة الآفات للمبيدات. يمكن للمكافحة المتكاملة للآفات الإسهام نظرياً وعملياً في استدامة الإنتاج الزراعي. كان هناك تركيز، في العقود الثلاثة الماضية من القرن العشرين، على أهمية استخدام المكافحة المتكاملة بهدف التنمية المستدامة. وقد نتج هذا التحول من جراء تكامل العديد من العلوم الأساسية والتطبيقية لتطوير عناصر وقاية النبات ونشر المعلومات حولها. وتشمل هذه العلوم الاجتماعية كعلوم الإقتصاد، الإجتماع ودراسات الجنوسة. كما تضافرت جهود القطاعين العام والخاص في إجراء البحوث وتطوير تقنيات وقاية النبات، وكذلك الإنتاج، التوزيع، التطبيق، التبني والتقويم في الحقل.

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