Extension Plant Pathology

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Abstract

Phyto health care is a holistic approach and the most pressing need to serve the poverty-stricken farmers by extension services, especially in developing countries. Extension programs can prove fruitful tools to minimize plant disease losses by assisting and educating farmers in developing countries in order to increase their productivity, food security, and livelihoods. Phyto health clinics are accountable and responsive. Previous studies have revealed significant lessons about the most effective ways to set up phyto healthcare clinics, educate phyto doctors to provide a trustworthy service to farmers, and lay the groundwork for developing plant health systems that integrate efforts and resources for increased impact on farmers' economic status. The participatory action research approach has made it possible for us to pinpoint research priorities precisely and has given us a better understanding of the constraints faced by farmers. The main aim of this effort is to throw light on the significance of phytopathology extension, the role of plant pathologists in phyto healthcare, and an overview of phyto healthcare in the developed and developing world.

Keywords

Plant health · Pathological issues · Plant health diagnostic network · Phyto clinic · Global biosecurity

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13.1 Phyto Healthcare for Poverty-Stricken Farmers Across the Globe: A Pressing Need Extension Plant Pathology

Extension plant pathology aims to build educational programs that offer guidance on prompt detection and management of plant disease to increase farmers' productivity, food security, and means of subsistence.

Programs for extension are required to help increase farm income and production and decrease food insecurity and poverty. Extension programs involve teaching techniques and skills to improve farmers' productivity, food security, and means of subsistence. In agricultural-dependent economies, extension programs have been the primary means of disseminating knowledge on-farm technology, promoting adult learning in rural areas, and helping farmers to improve their managerial and technical farm skills. With a focus on the agricultural extension services offered by the ACDEP, the impact of extension services on-farm production and income has been investigated (Danso-Abbeam et al. 2018).

Since the Smith-Lever Act of 1914, which established extension, it has significantly changed (Sherf 1973). It deals with extension programs designed to minimize plant disease losses by assisting and educating county extension agents and producers through the county delivery system. Early outreach, a hallmark of extension plant pathology, is described as a one-way process in which the institution communicates its knowledge to crucial elements (Spanier et al. 2001). Over the past century, changes have also been made in the diversity of the network that shares plant pathology knowledge. Growers rely on the diagnostic services and adaptive research carried out by extension plant pathologists and information from non-profit organizations, for-profit companies, and paid consultants. Companies, associations, or consultancies rarely do independent research. The Rodale Institute and the agricultural chemical sector stand out. However, most of these sources of information have a narrow scope because they concentrate on a specific set of issues or strategies. For instance, non-profit organic organizations can't even teach growers how to use a genetically engineered disease-resistant cultivar, even if doing so is economically and environmentally advantageous. Agrichemical suppliers who sell specialized chemicals frequently offer advisory services to growers (Everts et al. 2012; Ul Haq et al. 2020).

13.1.1 Extension Plant Pathologists

Plant pathologists who work in extension programs recognize plant diseases, offer guidance, and conduct research on regional and local phytopathological problems. Although the job of an extension plant pathologist has evolved through time, the need to be knowledgeable about every facet of our profession and be able to apply and successfully communicate that information to a broad audience does not appear to have altered. The purpose of extension has always been to act as a "translator" between the university and its customers, including nurserymen, agribusiness owners, farmers, homeowners, consultants, and a wide range of other people. The first officially hired extension plant pathologists were M. F. Barrus of Cornell and R. E. Vaughan of Wisconsin in 1915. Extension plant pathologists planned and conducted short courses, farmer institutes, and local grower meetings during this time. Plant pathologists have already begun working on extension publications and demonstration initiatives. Extension plant pathologists eventually coordinated their work through county agents as the county agent system grew more established. County agents were responsible for communicating the local community's requirements to state-based extension specialists (Jacobsen and Paulus 1990).

13.1.2 Need for Extension Phytopathology

If not addressed, there would be a delay in responding to developing diseases, lower crop yields, more significant economic losses, and a disadvantage for US agriculture on the global stage due to the increasing demand for reliable information and continual budget cuts at the local, state, and federal levels (Everts et al. 2012). Over the past 20 years, numerous extension plant pathologists have worked at regional or extended research centers. However, the APS extension committee met for the first time in 1931.

13.1.3 Scope of Extension Phytopathology

Extension phytopathology is bringing scientific investigations to the public. Extension plant pathologists are still an essential part of the APS, accounting for 9% of the organization's membership in the United States (Jacobsen and Paulus 1990). Extension plant pathology programs have changed throughout the past century to account for changes in program funding and the US population's demographics. In response to a highly educated customer, extension programs are becoming more collaborative and specialized (Everts et al. 2012).

13.1.4 An Overview of Plant Healthcare in Developed and Developing Countries

Despite a recent concern for extension, a dearth of innovation in advising approaches has resulted from historical neglect. However, in developing countries, extension programs perform a terrible job of aiding farmers. Although governments employ a substantial number of extension specialists, they have a limited understanding of farmers' needs, and farming communities are scattered (Anderson 2007). Because farmers have few steady and trustworthy channels for communicating their requirements, even the most excellent extension workers cannot meet the demands of all their assigned customers. It is time to reevaluate how to best address the requirements of farmers, especially in developing nations where agriculture serves as the primary source of earnings for millions of people.

Phyto health clinics are not a novel concept in the USA and other developed regions of the world with successful phyto health systems that help farmers and have been doing so for a long time (Campbell et al. 1999). However, in the case of the developing world, phyto clinics present a new strategy for the farming community. The most pressing need is to serve the farmers by extension services, especially in developing countries. Extension programs can prove fruitful tools to minimize plant disease losses by assisting and educating farmers in developing countries to increase their productivity, food security, and livelihood.

13.2 An Insight into Participatory Approaches and Phytopathological Problems of Developing Countries

The use of pesticides imposed concerns on growers, agricultural workers, and users, and the centralized strategy came under increasing criticism. A new paradigm was needed to feed the world through sustainable food production (Schillhorn van Veen 2003). The centralized system (including state-managed input procurement) came under increasing criticism since the usage of pesticides posed risks to farmers, agricultural workers, and consumers. A new paradigm was needed to feed the world through sustainable food production (Schillhorn van Veen 2003). Farmers today must compete in markets where consumers expect low-cost and high-quality products. Pests (such as diseases and weeds) are becoming more capable of adapting to cutting-edge single technology-style crop protection and contributing to the problem. There is a need for holistic approaches to generating and sharing knowledge (Vos et al. 2010). Participatory methods are currently utilized more frequently, and several words and acronyms refer to various uses. The shared denominators include the emphasis on the target/end-user groups' active involvement in the discovery of innovative knowledge and the facilitatory contribution of trainers.

13.3 Emerging Plant Diseases in Developing Countries

Plant diseases significantly lower crop yield in tropical ecosystems and developing countries. These countries are especially vulnerable to spreading diseases because they lack the resources to control them. Major epidemics can substantially harm economies that depend heavily on agriculture, jeopardize national food security, and evict populations. According to current forecasts, cropping practices and international trade will lead to an increase in disease pressure. A detrimental factor might also be climate change. Ideal strategies for containing outbreaks should include prompt intervention, precise detection, and reliable monitoring. This is especially true for new diseases, which frequently need rapid development and innovative responses. Emerging infectious diseases spread by plant pathogens have the potential to develop into sudden and severe epidemics due to the interaction of various pathogen, host, and environmental variables. In the past, Europe endured catastrophic epidemics with adverse societal effects due to the continent's rapid urbanization and the fact that many other EIDs still regularly occur in the developing world.

At the start of the twenty-first century, Xanthomonas Wilt of Banana, which threatened the food security of nearly 70 million people in Uganda, caused yield losses of about 50%. (Vurro et al. 2010). The damaged area is expected to grow at an annual pace of 8% if the disease is not controlled (Kayobyo et al. 2005). According to predictions, the condition will cost at least $8 billion in damages over the next ten years or $2 billion yearly. Current research indicates that Uganda's banana crop will endure output reductions of about 53% during the next ten years. Cassava Mosaic Virus (CMV) is the most severe disease in Sri Lanka, Southern India, and Africa (Otim-Nape and Thresh 2006). CMD is a disease that can eradicate cassava farming in many parts of East Africa and lower yield by 80–90%. In Sub-Saharan Africa, a parasitic weed called *Striga hermonthica* destroys grain crops on about five million hectares (Vurro et al. 2010). Infestation rates in maize fields ranged from 20 to 30 percent of the total in Togo, Mali, and Nigeria, and Benin exceeded 65 percent in a review on the spread of *S. hermonthica* in 25 African countries (De Groote et al. 2008).

Due to the *Puccinia graminis* f. sp. *tritici* race Ug99 rust fungus, which adversely affects wheat in Uganda, most nations that farm wheat are in danger. A race known as Ug99, named after its discovery in Uganda in 1999, has recently produced severe outbreaks in several countries in East Africa and the region surrounding the Horn of Africa (Ethiopia, Kenya, Sudan, Uganda). Oman, Iran, Eritrea, Afghanistan, and Pakistan (FAO 2008b) were on the list of nations with an immediate risk of infection.

13.4 Participatory Methods

There are many applications for participatory approaches and numerous terms and acronyms to identify them.

13.4.1 Adopting Participatory Training

It is advantageous when information is available, whether at the researcher or farming community level. Such information is disseminated through problem-solving instruction that promotes the discovery learning process, which entails diagnosing or identifying the problem, researching the ecology and biology of pests, and then trying out various management techniques. During participative training, conventional teaching techniques must be abandoned. We refer to them as participants rather than trainees or students. In the past, farmers could observe tomato plants suffering from wilting in their fields but did not execute rouging because they were unaware that infected plants could spread disease to other plants. Farmers engaged in a field exercise where they performed the customary task of harvesting infected plants at the base of the stem and placed a portion of the infected stem into a glass containing water to detect the bacterial ooze (Vos et al. 2010).

13.4.2 Participatory Research

Participatory research may be helpful when conventional wisdom and scientific counsel clash or when there are no effective solutions to farmers' concerns. There are several definitions, but broadly speaking, the farming community designs agenda, analyses, and develops technologies following personal needs with the help of enablers and resource people.

There are various definitions, but generally speaking, with the help of facilitators and resource people, farmers determine the agenda, conduct assessments, and develop technologies according to their needs. Farmers must take the initiative and participate more actively in the field activities because the results are unknown, even if there are few procedural distinctions between participatory training and participatory research (Vos et al. 2010). Although direct empowerment is frequently restricted to small farmers when conducted by research groups, participatory research can also lead to farmer empowerment (Hellin et al. 2008). On organic smallholdings, a collaborative assessment of biological and cultural management looked at seven biological treatments utilizing a variety of *Clonostachys* and *Trichoderma* species and weekly and monthly phytosanitation. For the best results, farmers choose a mix of cultural and biological control. Because there was no alternative method for biocontrol at the time, weekly phytosanitation was still necessary. However, with appropriate biocontrol, pod sporulation can be avoided, and the phytosanitary process is becoming less labor-intensive (Vos et al. 2010).

13.5 Impact Assessment

A collaborative effort between scientists and farmers can also be used for impact assessment. Farmers should be urged to maintain their records in order to aid this process. Farmers will express interest in continuing the activity in their worksheets once they see how important keeping notes is. The breadth of FPR's coverage has drawn criticism (Farrington 1998). The recommendation domain is used to identify the population sample and to create a plan for maximizing the advantages of farmer involvement in events (Conroy and Sutherland 2004).

Adopting participatory approaches requires adopting prescribed practices and methods, making their successful implementation a difficult task. At present, extension workers must interact with numerous sectors, each with its own institutional and personal history, conventions, values, and interests. Farmers will come to know about plant diseases and management strategies. It will prove a beneficial step for effective learning of farmers.

13.6 Technology Espousal: Farmers' Participation and Training in Pakistan

Pakistan is an agriculture-based country. Most Pakistani citizens, whether directly or indirectly, depend on agriculture for their daily needs. The Pakistani government has begun several initiatives to educate farmers (Iqbal et al. 2016) and to provide food supply, combat poverty, and access services such as education and healthcare. Smallholders must be able to generate sustainable income. Sustainable productivity lessens the negative impacts on the environment and natural resources. The delayed adoption of modern technology in Pakistan is the most significant barrier to better smallholder yields.

13.6.1 The Cotton Industry in Pakistan and Constraints Faced by Farmers

The country's backbone is cotton. Over 1.5 million farming families are employed, while millions of workers in cities and towns depend on it for their livelihood. Up to 40% of the financial income of rural households in cotton-growing regions comes from selling cotton-related products. In addition, it generates around 85% of our domestic oil production and 60% of our export revenue. The province of Baluchistan has become a significant region for cotton production in addition to the central cotton-growing areas of the Punjab and Sindh provinces (Baluch 2007). Boll rots, root rot, and wilts are the three main fungal diseases. Bacterial blight, caused by *Xanthomonas campestris* pv. *malvacearum* are the most ravaging phytopathological issue. Bacterial blight is the most harmful disease that significantly reduces cotton yield during the rainy season (Delannoy et al. 2005). The United States' state of Alabama was where it was initially documented in 1891 (Atkinson 1891). The most notable factor limiting cotton output in Pakistan is CLCuD (Sattar et al. 2017). A new challenge to cotton growers is cotton boll rot and bacterial seed with 10–15% yield loss (Hudson 2000). Many fungal species cause cotton seed rots and seedling infections. Pythium (Devay et al. 1982), Rhizoctonia (Brown and McCarter 1976), Fusarium (Klich 1986), and Thielaviopsis are the main fungal genera linked to seed degradation (King and Barker 1934). These infections infiltrate the vulnerable cotton plants and cause damping-off disease. Farmers' poor technical proficiency and the lack of a productive extension agency, which limits access to and dissemination of new information and technology, make these problems much worse (Guest et al. 2007).

13.7 Participatory Action Research

Farmers are both participants and researchers in participatory action research. The primary goal of PAR was to draw attention to troublesome situations or concerns that participants believed required more research to make effective practice improvements (Cornwell 1999). The program aimed to provide farmers with efficient disease management solutions. The idea that PAR provides various valuable and affordable solutions is one of its advantages.

The results of the several research that examined the effects of Bt cotton in developing countries are generally restricted to comparing the average outcomes for adopters and non-adopters. The findings of the several studies that looked at how Bt cotton affected developing economies were usually limited to a study of the average results for consumers and non-consumers. Concerns and questions have been raised about the commercial use of Bt cotton in Pakistan due to a lack of thorough research on the economic growth of the readily accessible Bt varieties relative to traditional types and a variety of pest risks in the country (specifically losses brought on by the CLCuV, which is dispersed through the white fly). To assess the financial impacts of the adoption of unapproved Bt varieties on costs of production and yields, the "Bt Cotton Survey 2009" (IDS 2009), a questionnaire-based survey, was conducted in 2009 in two cotton-growing districts of Pakistan: Mirpur Khas in Sindh and Bahawalpur in Punjab (Becker and Ichino 2002). Between 2006 and 2008, Bt cotton adoption grew quickly in these two districts, following the general trend. Bahawalpur had a higher adoption rate (36%) than Mirpur Khas in 2006 (32%). Bt cotton was grown by slightly more than 87% of farmers in Mirpur Khas in 2008, compared to 74% in Bahawalpur (Nazli 2011).

13.7.1 Significant Management Options for CLCuV

A variety of several minimal, moderate, and high-input IPDM solutions were introduced in response to the realization that management approaches needed to change. These alternatives served as the basis for contemporary, grower-focused methods of disseminating cutting-edge knowledge and methods (Konam et al. 2008). The objective was to increase cotton production and increase farmer incomes. By adjusting optimum crop techniques, the disease could also be controlled. The severity of the disease would be minimized by planting cotton between May 15 and June 15. CLCuV infection is reduced by about 20–30% by applying potassium fertilizer at 100 kg K2O and 150 kg N per hectare. In the cotton belt of Punjab province, disease prevalence varies substantially naturally depending on location (Baluch 2007). The participatory action research approach has made it possible for us to precisely pinpoint research priorities and better understand the challenges faced by farmers and what is and is not working. Because they were immediately involved in implementing the improved management and spreading it among their neighbors, it gave farmers more responsibility by demonstrating the immediate consequences of technology.

13.8 SoTL Projects in Phytopathology

Teaching efforts valued on par with scholarly activity, such as research in our professions is the aim of those who promote scholarship learning and teaching. When a teacher faces a severe issue, it is typically considered a negative situation that must be addressed with caution (Bass 1999). A founding member of the movement for the scholarship for learning and teaching claimed that it is appropriate for a scientist to teach, trying to provide the fairest and most realistic description of the latest information to those who would like to secure knowledge, in addition to discovering the truth and sharing it with his colleagues. To become a scholarly teacher, one must reflect on their teaching and have a keen interest in learning more about the research behind effective teaching techniques. Such a method frequently entails articulating a problem, finding its solution, and performing a formative assessment to gauge its effectiveness (Bass 1999). A topic in education must be thoroughly investigated for SoTL (study of teaching and learning), and the results must be shared with people through presentations or publications. This knowledge might then be used to develop a framework for other teachers (Hutchings and Shulman 1999).

13.8.1 Scholarship of SoTL Projects in Our Classroom

As academic educators, we want to know if the materials we offer and the teaching strategies contribute to improving student learning (Eastburn and D'Arcy 2010). This inclusive classrooms phytopathology course provides an introduction; we shall present three SoTL investigations. Students of phytopathology learn about the main crop plants and the most significant diseases that affect them. Students are also addressed to agricultural issues such as mycotoxins, pesticides, genetic engineering, food safety, environmental quality, monoculture, and food production through the use of these plant diseases.

13.8.2 First Example: Productiveness of Various Media and Instructional Methods

We deliver material in a variety of instructional formats and media, including videos, small group activities, traditional lectures, books, websites, podcasts, response devices for students' in-class and out-of-class writing assignments, to accommodate variation and diversity of our students' majors, backgrounds, genders including learning styles (D'Arcy et al. 2007). Therefore, these media might be beneficial for a variety of student groups. Students from various majors, learning styles, and genders judged a range of teaching strategies and media as helpful in this study. Eight teaching techniques, such as PowerPoint slides, review grids, online quizzes, lectures, overheads, PowerPoint notes, and blackboard notes, were evaluated as successful over the course of two or more semesters through each of the four learning style groups (scientific and non-science majors group and both genders group). Practically speaking, it is good that different student groups found these strategies helpful, and it supports the notion that various teaching strategies and media benefit all students (Eastburn and D'Arcy 2010).

13.8.3 Second Example: Effectiveness of Web-Based Assignments

A second study was carried out to determine the effect of a supplementary course website on student learning. Data from the student survey were analyzed, and seven key themes about student site usage emerged. More student control over information access, more learner speed control, and a wealth of knowledge resources are all provided via the internet. Practical learning of students is possible by writing, and they can explore the field through interactive components such as available online laboratories, including dynamic simulations, while the internet allows for in-depth research and phenomenon investigation (Bruce et al. 2005). We lacked any complex data showing that utilizing the site had enhanced student learning, even though input from students suggested they enjoyed using it and thought it aided their in-class learning. We were able to determine the impact of the productive activity on the learning of students through a comparison of results of comprehending and applying the scientific method pre-test questions to those on questions with a similar phrasing on the post-test. As a result, the potential of students to explain the scientific process's main ideas and apply what they learned to particular circumstances significantly improved.

13.8.4 Third Example: Significance of Course Information to Daily Lives of Students

As educators, our goal is for our students to understand the significance of what they learn in school and use it in their everyday lives. In the Plants, Pathogens, and People course, we undertook third research to learn more about how students adapt what they learn in the classroom to their non-academic lives. According to the entries in the student journals, students most frequently referred to information directly related to their everyday lives in non-academic contexts, usually information about food or addressing current events in the news. It was clear how writing to learn, and outside-of-class writing assignments impacted the transfer of knowledge. The findings of this investigation support utilization of news articles, writing prompts including narrative training to achieve this goal and our emphasis on the personal significance of each student's choice of topic.

13.8.5 Need for Scholarship of Teaching and Learning

A similar argument is that psychologists and educators should be enlisted to carry out these investigations since we lack the expertise necessary to carry out significant research in teaching and learning. Faculty members should conduct SoTL research to increase their effectiveness as teachers. The second component that flows from the first is the enhancement of student learning inside and outside the classroom. The advancement of education for individuals working in the field of phytopathology, if not the entire academic community, is a third reason why plant pathologists engage in SoTL research. Although education researchers and scholars have generated a large amount of data that is essential to our schools and could be used to improve our effectiveness as teachers, these individuals lack the time and motivation to adapt their data for learning to all of the fields of study in which it may be useful. Another benefit of including experts in phytopathology in SoTL research is the more prolonged exposure to phytopathology. Because we conducted research in our classes and then presented our findings at teaching seminars and workshops on campus or as presentations and posters at teaching-related professional meetings, many more people are now aware of the field of phytopathology. They are at least somewhat familiar that plant diseases affect their daily lives. We believe it is essential to do SoTL research in plant pathology, despite the many difficulties and perhaps unsatisfactory results.

13.9 A Glimpse into Experience of Technology Transfer in Extension

13.9.1 Technology Transfer in Extension

Technology transfer (TT) is an important step in the extension process, which involves sharing technical knowledge and innovation with the farming community (Koutsouris 2018).

13.9.1.1 Role of Internet

In its simplest form, the internet can be considered a vast network of computer networks. Text, graphics, photos, sound, and video are just a few of the several media types used to deliver information online. Staying updated is now possible in ways that were never before practicable. In 1997, the Van Buren County Extension Horticulture website included weekly updates on disease situations, including a fire blight pandemic. The Clarksville Horticultural Experiment Station regularly updates important data on the occurrence and prognosis of apple scab (Biggs and Grove 1998). In 2004, *Phakopsora pachyrhizi*, responsible for Asian soybean rust, probably invaded the country via the winds from Hurricane Ivan. With the introduction of the internet, extension advisories, publications, and diagnosis tools have continued to be available to people and other interested individuals.

With just a few clicks, growers may quickly access various educational resources, such as books, digital pictures, downloadable PowerPoint presentations with narration, and instructional video clips. Remote PowerPoint presentation access via personal computers is becoming more common in America (Vincelli 2010). Since some consumers find it difficult to distinguish between these disparities, recent efforts have been made to build websites that offer quality-controlled information about agricultural research. IPM Images is one example of an image database that is easy to use and access. One of the many searchable and user-friendly image databases accessible online is IPM Images. Fact sheets for several websites and a collection of diagnostic images for the NPDN are more examples (Vegetable MD Online). These websites are all consistently updated (Jacobson et al. 2008). Universities and some business interests have created web-based techniques that diagnose plant diseases without actual plant specimens and instead rely on digital pictures. The initial concept depends on the accurate GPS location of the seed tablet (Griepentrog et al. 2006). Real-time kinematic approaches (RTK) must be ordered from nearby vendors, and an extremely precise GPS signal is needed for position-based systems. The widespread use of smartphones and recent advancements in computer vision made feasible by deep learning have made smartphone-assisted disease detection conceivable. Smartphones, in particular, provide highly specialized methods to help with disease detection due to their computer power, high-resolution displays, and extensive built-in accessory sets, such as full HD cameras (Mohanty et al. 2016).

13.9.2 Alterations in the Role of Extension Specialist and Information Flow

Farmers can now find information from various sources, including seed distributors, fungicide manufacturers, advisors, fertilizers suppliers, information from other countries' extension programs, and peer-reviewed journal publications. Specialists should safeguard their standing as objective, science-based authorities by ensuring they uphold that standard in all they do if they want to ensure that extension remains applicable in this present era. Extension professionals have a unique position in that they may provide helpful research and recommendations that are typically viewed as objective and the most cutting-edge diagnostics, despite the fact that producers acquire information from several sources (Vincelli 2010). A rising number of programs in applied phytopathology use molecular tools to identify the pathogen. When *Phytophthora ramorum* causes rapid oak death, identification using nucleic acid-based methods is necessary to complete the diagnosis. Innovative technologies are helpful, but it's crucial to remember that to utilize them successfully, one must be aware of both their disadvantages and benefits. A recent review article on pathogen detection based on nucleic acid addressed these issues (Vincelli and Tisserat 2008).

13.9.3 Extension Programs in the USA

Extension programs have been implemented globally to enhance human capital by educating farmers on production techniques, the best input usage, and management techniques (Dinar et al. 2007). Most of the almost one million extension workers who provide daily advice to farmers worldwide are situated in low- and middle-income countries, particularly in Asia, where they make up 70% of the total (Bahal 2004). The West Africa Agricultural Productivity Program (WAAPP) is a significant extension initiative. The program was started in 2007 and operated in 13 countries in West Africa. It develops and disseminates climate-smart farming techniques to increase long-term agricultural productivity (Caiafa and Wrabel 2019). Plant pathology is involved in some of these areas, while it has little technical significance in many others. Despite numerous successes, critics claim that extension systems fall short due to low staff morale, financial strain, poor interactions with agricultural research, the improper use of extension officials for political ends, or the failure to maintain farmers' interest in training over the long term (Jones and Kondylis 2018).

13.9.4 Privatization of Extension Services in USA

It is crucial to remember that it is acceptable to question if a for-profit or a private company would be more appropriate to execute the services plant pathologists do as an extension in a capitalist society. However, extension specialists offer crucial services to community, including unbiased disease control advice, objectively applied research, and cutting-edge diagnostics for our forests, fields, and landscapes. Fortunately, at least among state and federal legislators, society appears to recognize this. There have been no significant proposals in the USA on privatizing extension services. This approach would damage both by severing ties between the extension and the land-grant university (Vincelli 2010).

13.10 Diagnostic Networks: A fruitful Tool for Plant Biosecurity

13.10.1 Significance of Plant Health

Most species, including humans, depend on plant systems for various ecological services. Systems for producing food and maintaining public health are founded on plant systems. It is exceptionally challenging to guarantee sustainable food security because of the complex networks involved in making food and transportation, reliance on availability and energy cost, and their vulnerability to political unrest (Anon 2008). Many medications are prescribed for cognitive and psychosocial issues and used to treat diseases obtained from plants. For the foreseeable future, plants will be essential in preventing rises in atmospheric carbon dioxide concentrations. If harnessing plant-based energy is a practical solution for reducing the negative consequences of climate change without jeopardizing food security, healthy plant systems are required. People have prized plants for their aesthetic value throughout history and worldwide. The multibillion-dollar (US) sector of international trading in ornamental and landscape plants boosts many countries' local and global economies (Stack 2010).

13.10.2 Constraints to Sustainable Phytohealth

One of the many factors that can influence phytohealth is the obstacles created by biological weapons, bio crime, climate change, the increasingly globalized populace, and foreign trade (Stack 2008). Technology and research development will require financing to address these issues and safeguard the plant systems that sustain life and ecosystem preservation. One of the most pressing challenges is global plant and product commerce, combined with population growth and development. The relative significance of purposefully introducing plant diseases is difficult to assess, and there has been much debate on the subject (Young et al. 2008).

13.10.3 NPDN (The National Plant Diagnostic Network)

The Cooperative States Research, Education and Extension Service of the USA, in collaboration with the land-grant university system, established NPDN in 2002 to aid in protecting plants from the intentional, unintentional, and natural introduction of phytopathogens and pests (Stack et al. 2006). The primary goal of the NPDN's establishment was to identify disease outbreaks and the agents responsible for them quickly. Common diseases are most frequently identified based on the typical symptoms and objective evidence of diseases detected during diagnosis. The likelihood of misdiagnosis in the field depends on the expertise of the field specialist and the disease's local epidemiology. Getting laboratory confirmation of a diagnosis is essential for any disease with a significant risk of adverse consequences. As the diversity of the sample and the significance of the diagnosis increase, a diagnostic laboratory employs increasingly cutting-edge technologies. To identify regulated infections, extremely comprehensive molecular diagnostic approaches are typically needed (Stack 2010).

A thorough evaluation of the capacity and competency of each plant diagnostic laboratory was necessary due to the discrepancy in core competencies and diagnostic infrastructure among laboratories across the country. The idea behind triage is to differentiate between positives and negatives. The triage procedure, in concept, starts when the evaluation of the type of issue is made in the field at the epidemic site. This facilitates the quickest response possible by accelerating the diagnostic procedure.

Web-enabled microscopy and video conferencing are available at many NPDN laboratories. As a result, a diagnosis in a lab can send a picture of the material being examined under a microscope to a mini server, laying the groundwork for a functional telemedicine system. The URL to a webpage on the microscope server is then communicated to an authority on that pathogen or host, for example, by email or phone.

A speedy and precise determination is one of NPDN's key objectives. In plant clinics, without widespread access to contemporary technologies, the physical and cultural characteristics of the pathogen are used for traditional diagnosis. This presents a few potential challenges for different infections. A diagnosis based on physical and cultural traits can take much time to improve the effectiveness and accuracy of diagnosing a plant disease. Through NPDN funding, grant funding, and assistance from host universities, the technologies necessary for current nucleic acid-based assays, like PCR and real-time PCR, were made available to NPDN laboratories. Thermocyclers, real-time thermocyclers, ELISA plate readers, gel documentation systems, and other variants of this equipment are available (Stack et al. 2006). For this laboratory network and screening system to be most effective, the results generated by each laboratory must be of specified quality to inspire confidence in the results and to permit the interpretation of shared information.

A national system for laboratory accreditation (LAS) is being created to fulfill this goal. Under this program, all NPDN labs would get the equipment and instruction required to meet the accreditation requirements for an NPDN diagnostic laboratory. Purdue University established a nationwide database for diagnoses from all NPDN labs. This data source presents insight into the regional prevalence rate of pathogens. Additionally provided is a database for epidemiological evaluations of the dynamics and trends of the disease. In the event of an intentional introduction, the data repository will give background data for forensic analysis (Fletcher 2008).

Using NPDN laboratories in a ring testing technique, USDA research facilities have enhanced the validation of novel diagnostic tools (Lamour et al. 2006). Providing the diagnosticians with extra training in the protocol before it was put into place as a standard operating procedure has improved the protocol validation. Additionally, the NPDN diagnosing labs have been requested to provide funding for studies comparing various diagnostic technologies in scenarios where an epidemic is present as part of research projects linked to disease outbreak response operations (Bullock et al. 2006).

13.10.4 Communications Infrastructure and Operations By NPDN

To enable information sharing amongst diagnosticians and regulatory agencies, NPDN created a secure communications infrastructure. The NPDN provides a web portal that acts as a public information resource and a gateway to each regional network's website. The communication system was designed to prevent unwanted physical or electronic access to network data and guarantee data accessibility and integrity against various human and environmental threats, such as vandalism and extreme weather conditions (Stack and Baldwin 2008).

13.10.5 Training and Education Program Developed By NPDN

An education and training program for first detectors was developed and implemented by NPDN. First responders are educated to recognize disease symptoms and indicators, as well as pathogen and insect damage that may have detrimental effects. NPDN training programs are presented in person, either in a classroom setting or in the field. There is also a functioning online system for first detector training that enables asynchronous program distribution.

To ensure the rapid and precise diagnosis of diseases and pests, Phyto diagnosticians must be instructed in using cutting-edge diagnostic technology and the most recent SOPs. The correct notification procedures, as well as the rules and laws governing the handling, storing, and transportation of specific agents, sample processing, and sample destruction, must all be understood by NPDN diagnosticians. The topics covered in the regional hands-on workshops provided by NPDN include insects (such as *Maconellicoccus hirsutus*), infections (such as Wheat Streak Mosaic Virus), diagnostic tools (such as PCR), and vectors (such as *Aceria tosichella*).

A method to help states prepare for an outbreak of a plant disease was developed and implemented by NPDN. Each exercise is based on a well-constructed issue that describes the protocols needed for a successful response to and resolution of an outbreak of insect pest or disease. Asian soybean rust, *Agrilus planipennis, Agrilus marcopoli,* including other epidemics, have been modeled in scenarios. A computer software program is used to manage each exercise, giving all the data required for detailed post-exercise evaluations.

13.11 An Overview of International Cooperation for Global Plant Biosecurity

Plant diseases seriously threaten world food security (Strange and Scott 2005). Because of the rising hazards associated with the widespread movement of plant products and plants across the world, international collaboration is essential for ensuring plant biosecurity (Stack and Fletcher 2007). The plant diagnostic facilities of business partners, bordering countries, and those situated along natural trade routes in North America should be connected to international networks (Main et al. 2001). The European Union created the Crop Biosecurity Program to introduce a research network focusing on harmful diseases of plants under the direction of the University of Torino (Gullino et al. 2008). This network aims to include more European and Mediterranean countries and secure communications technologies to enable coordinated diagnosis (Stack and Baldwin 2008). Regional labs have been introduced in Africa, the Caribbean, Central USA, and Southeast Asia through the NPDN paradigm. For regional plant diagnostic clinics, many nations have created and made diagnostic training programs available. In countries with limited resources, IPDN will substantially impact ongoing investment.

13.11.1 Plant Health Clinics and Plant Pathology Training

The agricultural industry plays a significant role in increasing nutrient-dense food, guaranteeing food security, and reducing poverty worldwide (Jones and Ejeta 2016). Despite the significance of agricultural crop production, insect and disease infestation generate problems along the value chain of crop production. Plant pests and diseases that are economically significant cause about 40% of agricultural output losses (Oerke 2006). Plant health difficulties can be treated by correctly diagnosing and identifying pests affecting agricultural plants (Ausher et al. 1996). Farmers can obtain advice on plant pest problems affecting crops through plant health clinics and management strategies for pest control (Alokit et al. 2014).

13.11.2 Training in Crop Protection at UCL

The main training objective has been to provide specialized training in plant protection without compromising the need for multidisciplinary skills and adapting to changes in agriculture and the job market ever since the Integrated Crop Protection opportunity was set up at our faculty in 1967 and throughout the numerous program revisions since then. The compulsory disciplinary training in crop protection includes lectures on organisms that affect plant development, such as viruses, bacteria, fungus, nematodes, arthropods, and weeds. Additionally, it discussed the interactions between pathogens and plants in epidemiology, case studies of harmful pathogen or pest interactions with plants in phytopathology and applied for entomology courses, and crop protection techniques in crop improvement, phyto pharmacy, biological, and integrative courses (Maraite et al. 2010). The phyto clinic course has been the basis of our plant protection curriculum at UCL since its inauguration in 1976. This course was created due to interactions with the plant clinic connected to the department of botany and phyto pathology at Purdue University in Indiana, USA, during the author's postdoctoral stay there in 1972. Applying the phyto clinic concept, as employed in an American land grant university, did not appear practical to the UCL scenario because developing a phyto clinic service was not UCL's top priority. The author defines a plant disease clinic as employing actual field samples of diseased plants, integrating scientific knowledge to understand, prevent, or treat the observed disease, and training plant doctors (Evans-Ruhl 1982).

The phyto clinic course begins in the fall with one or two outdoor sessions designed to teach students how to identify disease or pest injury symptoms, examine the distribution of the symptoms, gauge the prevalence and severity of the disease, and assess the likelihood of further development of disease. The following 10 to 15 weeks are spent instructing the students to diagnose illnesses in the lab more quickly and accurately. A Leica M3/M5 stereomicroscope, a Zeiss Axiomat light microscope with phase contrast and dark field, a box with tools and chemicals for slide preparations, and isolations of pathogenic fungi and bacteria are all present in the lab for the plant clinic course, which has 15 student workstations.

It is let out to identify particular cultures using PCR or electron microscopy in collaboration with a mycological lab. Small groups of students are also instructed on the practical use of ELISA tests and PCR testing for mycotoxin and fungus detection in addition to conventional procedures.

13.11.3 The Plant Clinic Service: A bridge that connects the University and Farmers

Under the auspices of CORDER, the plant clinic service has been created since 1985. Employees were initially compensated through a regional program to lower unemployment, supporting public interest initiatives. Due to service agreements with individuals and organizations, client fees, and occasionally a reimbursement from the Walloon Area for the social service provided, the budget has expanded to approximately €350,000 per annum. In compliance with CORDER, space may be rented from the UCL Lab of Phytopathology, major equipment may be shared, and the library and L3 Biosafety Laboratory may be used for work involving quarantine pathogens. As a result, the phyto clinic service acts as a conduit between farmers and the university.

13.11.4 The Linkage Between the Phyto Clinic Course and Phyto Clinic Service

The university's phyto clinic course and the non-profit plant clinic service work well together. On occasion, the course will incorporate additional analysis of intriguing samples sent to and evaluated by the service. Through their interactions with the service, the students learn about the purposes and specifications of a phyto clinic service. Both the course and the service share the paperwork for the phyto clinic. Around the time of their training's conclusion, which usually occurs in May, the most experienced students are allowed to participate in the analysis of specific samples delivered to the phyto clinic service. After the analysis, they provide the service bioengineer with their diagnostic and recommendations. These samples can be added to the herbarium for their Plant Clinic course. Many students make use of the plant clinic program. Furthermore, plans have been established for specialized instruction in the strategies employed by the plant clinic service (Maraite et al. 2010).

Specifically, in terms of phytopathology and the study of plant health, the plant clinic course helped increase one's awareness of adequate crop protection. The sharpest students may grow frustrated if there is a significant disparity in the group's pre-course training levels, even though they view the integration of knowledge through group discussion as a plus. Phytopathology training and plant clinics cannot be linked individually. Each university must choose the best strategy based on its resources, environment, and goals.

13.12 Technology Exchange Between China and Italy for Sustainable Crop and Environment Protection

Both highly developed and developing countries currently face new issues in agriculture. In developing countries like China, where 60% of the population still lives in rural areas, in poor conditions, and depends on agriculture as their primary source of earning, a shift toward sustainable agricultural systems which are more diverse (OECD 2005). A key component of sustainable agriculture is plant protection. Discussion is had regarding the results of an eight-year partnership between Italy and China in sustainable plant protection.

13.12.1 Significance of Agriculture and Agricultural Research in China

China is a major agriculture-based country. Considering the size and significance, China's agricultural economy is receiving much attention and becoming increasingly important to global trade. Nearly 15% of the GDP and more than 40% of jobs are accounted for by agriculture. Around 200 million farms, with an average land area per household of 0.65 hectares, are engaged in small-scale farming, dominating agricultural production structures (OECD-FAO 2008). China's agricultural performance would have a huge impact on the global food and agricultural markets and the fight against poverty worldwide (Dong et al. 2006). Plant protection has become a vital academic and professional area in China. Most agricultural colleges and universities offer this particular area of study, and most townships have technicians trained in plant preservation. Most agricultural science academies above the county level have established research facilities, crop protection, and quarantine.

From 1998 to 2006, the state allotted 2.58 billion yuan for constructing fundamental infrastructure for plant pest emergency control, monitoring, and early warning. The government budget provided 272 million yuan in 2006 to monitor yellow rust (*Puccinia striiformis*), snout moth larvae, and plagues of migratory locusts (*Locusta migratoria manilensis*) (*Crambus agitatellus*). Environmentally friendly pesticides increased from 3.1% to 18.1% in 2006, whereas highly toxic and lethal pesticides dropped from 21.8% to 11.8%. Through a combination of law and technical transfer, advancements in the safe use of pesticides are still being made. These efforts significantly enhanced plant protection methods, better working conditions, and improved protective capacity (Gullino et al. 2010).

13.12.2 Technology Exchange Between China and Italy in the Discipline of Sustainable Crop Protection

The Sino-Italian Cooperation Program for Environmental Protection was introduced in 2000 by the Italian Ministry for Environment, Land and Sea and the China State Environmental Protection Administration. Since then, this framework program has carried out several projects in sustainable plant protection (Clini et al. 2008). Every project has as its primary goal the reduction of dependence of China on the use of chemicals, which poses serious concerns to both the environment and food safety. Finding alternatives to methyl bromide, a toxic fumigant used in the horticulture industry for pre-plant soil sterilization and banned by the Montreal Protocol because of its role in the depletion of the ozone layer, has cost much money since the inception of the Sino-Italian Cooperation Program (Gullino et al. 2003). Italy, which in the 1990s ranked second in the world for methyl bromide consumption and first in Europe for the production of horticulture products, developed significant expertise in the creation of workable and practical methyl bromide substitutes and made investments in the transfer of those technologies to other nations, particularly China (Gullino et al. 2003). Soil solarization, grafting onto resistant rootstocks, and the application of less harmful chemicals at reduced dosages via drip irrigation, tested on tomatoes and strawberries, were more well-liked by farmers despite providing levels of effectiveness comparable to methyl bromide. This is because they required less financial outlay and fewer adjustments to fit the traditional cultural practices (Dong et al. 2007).

Field tests under the Sino-Italian Cooperation Programme were conducted in Shouguang County, Shandong Province, east China, in 2006 and 2007. Three tomato rootstocks—Beaufort F1, Energy F1, and He-Man F1—were tested in one experiment to see how well they suppressed the root-knot nematode (*Meloidogyne incognita*) in a greenhouse environment. The results showed that the three rootstocks increased yields by 16–20% while reducing the occurrence of root knots by nearly 90% compared to a susceptible control (FA189 2008; Cao et al. 2008). Chemicals like flusilazole, carbendazim, metalaxyl, fenvalerate, and triadimefon are only a few examples that are no longer permitted in Europe and have been replaced with more natural and biological alternatives. The usage of pesticides on pears, for instance, was decreased by 29% and 69%, respectively, in comparison to traditional use, even though productivity was unaffected. In 2007, waxy maize pesticide use was reduced by 67% and 100%, while yields increased by 6% and 15%. Tomatoes and watermelons were cultivated in 2007 without the use of any chemical pesticides (Gullino et al. 2010)

13.12.3 Main Aim of Projects

The projects made an effort to adapt their objectives and methods of implementation to the particular locations they were focused on to adequately address those areas' unique social and economic needs, even though their primary purpose was to help China fulfill its obligations under the MEAMG. To discover, create, and carry out research and extension activities appropriately matched to local and global contexts, higher education institutions in China must develop the essential competencies. The inability to handle novel cropping systems and the lack of technical and scientific understanding have been two main obstacles to applying innovative techniques. Orienting scientific and technological expertise to meet market and industry demands is a difficulty. Due to environmental and financial considerations, which served as a steady frame of reference for all projects, fruit and vegetable crops were selected as the target crops. Although grains are still China's main crop, their proportion of total crop yields and planted area both fell significantly from 1990 to 2003 as other crops, like fruits and vegetables, became more lucrative and the government relaxed most of the policy requirements that had previously pushed growers to grow grains (OECD 2005).

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