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Future Challenges in Plant Pathology: What Lies Ahead for Crop Protection

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Abstract

Plant pathology is an important sub-discipline for the sustenance of world food security but has challenges that are progressively complex. Here the author discusses the Development Trends and Challenges that will define the crop protection systems in next decades. Changes in climate differ are also crucial since they affect distribution and virulence Of pathogens affecting plants. Managing these changes effectively is going to be very important in managing diseases effectively to enhance health of people. However, with the types of plant diseases re-emerging or newly occurring from time to time compounded by trade liberalization and climatic variation, plant diseases represent a increasing risk to food production. The emergence of these new threats requires accurate rapid detection and diagnosis, but existing approaches are usually inadequate, calling for improved surveillance technologies such as molecular diagnostics and remote sensing. Another major difficulty is the development of resistance, to chemical and biological control further the pathogens have tended to develop resistance to these methods. This goes further to call for the implementation of the integrated pest management (IPM), genetic variability and production of resistance crop through breeding and genetic engineering. Future direction in crop protection is therefore founded on new developments in biotechnology, especially gene-editing tools including CRISPR/Cas9 in the attempt to improve pathogen resistance at the gene level. Sustainability will form the base of the upcoming crop protection strategies as the world continues to advance. In the natural pest control system, possibilities are bio control agents,

organic manure, and IDM or Integrated Disease management which are considered environmentally friendly and effective than synthetic chemicals used in pest control. International collaboration, formulation of effective policies, and enhancing the people's commend about these improvements are required. The solution to future issues in plant pathology then will demand increased collaborative research efforts, technology, and sustainable practices in the future security of agricultural systems worldwide. This article reveals these challenges and gives a clear dissection on the necessary strategies in order to address them.

Introduction

Agricultural Plant Pathology has a very crucial role to play on food security by protecting plants from diseases, which can affect quantity and quality of produce. With the trends towards globalisation of agriculture, plant diseases represent an escalating threat to crop health and require the application of novel and sustainable methods of pathogen control. The directions of plant pathology are influenced by the climate, new pathogens, appearance of the resistant forms, and advanced methods of diagnostics and treatments. For instance , climate change through changes in temperature, humidity and precipitation affects the processes as regards disease identification, distribution, and intensity of diseases affecting plants. Climate uncertainty puts more pressure not only on farmers, but plant pathologists who have to learn new ways how to safeguard the plants from new forms of threats as well as more invasive diseases. This adaptation involves not only enhanced knowledge of the biological background of plant pathogens, but also more sophisticated approaches to scouting, diagnostics, and observation. At the same time, the discovery of new plant diseases, as well as the accelerated dissemination of existing ones because of globalization, is becoming a critical problem for world food security. The development of pathogen resistance to standard chemical control methods makes diseases even more challenging to control, hence the need to adopt IDM combining sources of resistance, biocontrol, and sound practices on sustainable agriculture. To these challenges, new technologies including gene editing, molecular diagnostics, and machine learning are emerging to change the view of managing plant diseases. These have the possibilities of better detection, higher response

rate and better methods of disease control. However, it also leads to questions regarding broader rules, regulations and policies, the theory of sustainable innovations and ethical issues

Climate Change and Its Dynamics to Plant Pathology

Global climate change is one of the biggest driving forces of plant pathology and its impact to plant diseases is slowly revealing itself. Increased temperatures, changes in precipitation, and the incidence of severe weather conditions are not only changing the pattern and regularity of the plant pathogens, but are also making it difficult to predict the level of crop damage. They point out that the physical environment alters pest survival, multiplication and dissemination rates; and host plant resistance to pests and diseases. It is thus established that factors such as higher temperatures can actually speed up the life cycle of most plant pathogens and make diseases develop and become more virulent faster. The warmer climates may also increase the area of the host geographical distribution, begetting the pathogens to copiously exist in a region that cannot support them in the old climate conditions. Said factor is especially worrisome due to the capacity of certain pathogens to spark new epidemics and destroy crops that may not be naturally immune to those afflictions. Whereas, fluctuations in rainfall that results to heavey rains or droughts may lead to conducive environment of fungal and bacterial diseases. During periods of high humidity, pathogen multiplication is favored, and disease transmission is more effective, on the other hand, water deficit negatively affects the ability of plants to handle diseases, the defenses are compromised. In the same way, high amounts of humidity encourage the development of the number one pathogen, fungi and oomycetes, which prefers moist conditions. Climate change also interferes with plant diseases' effect by reducing the integrated robustness of ecosystems and agricultural systems. Reduced ability of plants to defend themselves when under stress, together with fewer natural enemies due to fragmentation of habitats leads to fewer biological control agents against diseases. Mitigation and adaptation strategies have to be employed by researchers and agriculturalists to reduce the effects of climate change on plant pathology.Subsequently, three of the proposed measures include creating climate resilient plant varieties, enhancing stand-alone disease warning systems, and sustainable agriculture. Maize

disease control strategies in future will require climate change mitigation and adaptation in order to reduce future risks to Food Security caused by plant diseases.

Some of the coming and repeating plant pathogens.

The world agricultural situation is today on the spotlight for the appearance and reappearances of plant diseases, which greatly affect the production of food crops, food sufficiency and the economy. New disease or pathogens are termed as emerging because they previously affected only few geographical locations or are new diseases that have recently affected crops globally. There are two types of NDs: emerging and re-emerging NDs; while the emerging NDs are diseases that are novel and have cropped up because of some factors such as change in farming practices, virulent resistance or cyclical changes, re-emerging NDs are diseases that were earlier controlled, but have resurfaced for one reason or the other. There are several reasons that explain why such diseases spread and transform from one form to another Different Triangulation Technique. Some of these factors include, global trade and transplantation of seed and crops that help the pathogens to cross from one country to another and infect other host plants. Other factors that combine to increase the transmission of these diseases are globalisation and liberalisation of travel, combined with climate change and changes in land management practices that make probable that pathogens will have better environments in which to breed. The effects associated with newly-struggling and resurgence infections are numerous and large. For instance, Siegfried et al. ; Xylella fastidiosa, a bacterial pathogen that causes diseases including Pierce's disease in grapes has having devastating effects on crops in the United States and Europe. Likewise, Puccinia striiformis, responsible for the disease known as wheat yellow rust, has rearisen in recent years to wreak crop havoc, and pose a risk to global food supply. In order to counter these threats, the plant pathologists, are directing their attention towards the areas of enhancing the monitoring programs, diagnostic techniques and arriving at the genetically generated resistant crop types. The biologging of biochemical markers and the application of genomic sequencing, molecular epidemiology, and prescriptive analysis are the main factors improving the capacity to predict the geographic spread of infections and to react more quickly.

Moreover, new successful innovations in farming practices can slow these diseases prevalence for instance; crop rotation and integrated pest management practices. With climate change impacting the natural system, the emergence and re-emergence of new and potentially devastating plant diseases and pests will best be addressed through international cooperation and collaboration, research and the implementation of new effective disease management approaches.

Difficulties in Diseases Identification and Tracking

Disease diagnosis and surveillance are important to reduce the impact of plant diseases because they inform early intervention against plant pathogens. However, these processes experience the challenge that limits the timely interruption and augments the rate of crop devastation. The first is the notorious issue of heterogeneity these impediments arise due to the numerous and diverse types and forms of plant pathogens at the researchers' disposal. Diseases are often caused by pathogens such as fungi, bacteria, virus and nematodes; and plant diseases vary concerning their signs and the favourable conditions for their growth. Moreover, this is compounded by the fact that many diseases manifest similar signs and symptoms which makes diagnosis on this basis to be tricky at best. Such realities make it necessary for the growth of more accurate and highly efficient diagnostic methods. Another enormous problem relating to infection diagnostics is poor availability of diagnostic equipment, particularly in the Third World countries. Although PCR and sequencing techniques are effective to identify pathogens quantitatively and qualitatively respectively, these methods are expensive, equipment intensive and personnel skill dependent. As we have seen, for many farmers especially those operating small holder farming systems or in developing countries with limited resources, access to these tools is a challenge. This turns out to be a barrier that results in late or erroneous diagnoses and enables diseases to proliferate.

Even surveillance systems which are crucial for tracking the movement and distribution of plant pathogens by encounter some challenges. It is common to find surveillance activities poorly funded or poorly coordinated in many regions, and this hampers attempts at monitoring disease events and identifying new threats. Despite having surveillance systems in place, do not

necessarily have up to date data sharing and or linkages to agricultural extension service delivery, thus limiting the ability to timely inform farmers on potential threats. Additionally, the transfer of plant materials across borders, as well as climate change adds to the woes of tracing the pathogen as they can spread very fast and across borders.

Resistance Management and Development

Pathogen resistance developed over time is one of the major limiting factors in plant disease management. Long term management of plant diseases has proved to be a big challenge because pathogens can develop resistance to chemical pesticides, fungicides, and even to plant resistance genes. The phenomenon of development of resistance is inevitable under evolutionary pressure, when only those pathogens that have genetic mutations that provide resistance, reproduce and pass on such traits to subsequent generations. This the case because resistance when widespread may lead to increased disease intensity and crop loss thus being a threat to food security. Resistance can be manifested as alterations of the pathogen genetic material, alterations of the pathogen physiological features, or alterations in the environmental conditions influence the pathogen. When it comes to chemical resistant organisms could make developments in the ability to neutralize or alter the chemicals meant to be used to eliminate them. In plant breeding, pests and diseases can adapt to the introduced resistance genes, source of resistance and thus compromised on plant resistance.Control of resistance development is complex and must involve a package approach commonly known as Integrated Disease Management (IDM). IDM uses the chemical method, biological method and cultural method of managing pests in order to prevent resistance. One such tactic is the provision of a conscious cycle of various classes of pesticides or fungicides so as not to allow the mutual development of resistance to a given chemical. Further, resistant plant variety, when available, is an important strategy for disease control but it has to be used with caution – excessive use of resistance leads to recognition and selection by the pathogens. Use of bio-control agents, maintaining or enhancing the soil status, also managing the crop rotation are other practices that should also be employed to reduce the exploitation on pathogens hence minimize on resistance. Supervision and watching contribute significantly to

early identification of relevant signs of resistance, therefore managing them. Therefore, positive course of action, on research and adaptive management practices is crucial in managing the development of resistance to pests and in doing so achieving sustainable agricultural practices.

Impacts of Biotechnology and Genomics

Position: Pro-biotechnology and genomics have recently changed the perception of how humanity can better protect their crops and approach plant diseases. The successfully implemented of these technologies enables a selective and selective control of pathogens to a minimum use of chemical pesticides and contribute to environmental impacts. Enhancing the disease resistance is another area of genetic improvement for crop production while molecular breeding and genomic sequencing have improved surveillance and given out new tactics for the control of diseases. Molecular methods, including NGS, have enriched knowledge of the plant-pathogen associations. The genes of plants and pathogens may be compared for disease resistance and genes of pathogens that help them to penetrate plants. Such awareness can be used in creating plant varieties with capabilities of offering lesser resistance to particular diseases. For example, genes that carry information for resistance to diseases such as rust in wheat or blight in potatoes have been located in other crops and incorporated into new varieties of the crops hence providing stronger and appropriate resistance. Besides traditional genetic engineering, CRISPR-Cas9 methodology is considered to be effective in precise genome manipulations. This makes it possible that new crops can be produced with the improvement of certain genes related to disease resistance in plants. In what can only take a few years, unlike the crossbreeding process, CRISPR has the prospects of rapidly producing resistant variants without having to introduce new genes from other organisms. Biotechnology also has significant contributions towards improvement of disease diagnosis. Modern methods for analysis include quantitative PCR and biosensors that help to detect a pathogen at the early stage and act mannerly. Further, accuracy of disease distribution and pathogen dynamics facilitate forecasting and early detection mechanisms through genomic surveillance.

Disease Management Policies

International collaboration and policy making are critical in managing the increasing risk of PDs with far-reaching consequences on food security, bio-diversity and economic returns from agriculture. More and more plants are becoming infected with diseases due to the enhancement of trade across countries, climate change, and innovations in farming systems that call for collaboration with other world-representative to develop statesmanlike mechanisms in managing and eradicating diseases. Hitting on synchronized international polices make exchange of knowledge, resources and technologies possible which let countries to pool their efforts to protect agriculture systems all across the world. I international regulation and standardization are recognized as one of the key areas in worldwide collaboration in plant pathology. For example, the FAO, WTO and the IPPC are responsible for formulating and encouraging the implementation of measures for the safe transfer of plant products across national borders. These regulations enable the successive prevention of both the introduction of virulent pathogens into a country and the continuance of an unfair trade practice, namely that of protectionism.

Apart from policy support in plant diseases, international research cooperation is critical to solving the problems. National teams including plant pathologists, disease researchers and agricultural scientists from different nations have to engage in surveillance, monitoring and disease predicitive models. Information from international sources, as the databases maintained by the Global Plant Clinic, can offer where pathogens are located, what resistance they might have, or regimes that can be used to control them. Collective efforts can therefore help improve the existing stock of knowledge on disease resistant varieties, new diagnostic techniques, and efficient disease control mechanisms, with these being so expensive to develop individually by any one country. At national level, policy that support sound plant health needs to be put in place and there should be research, education and extension support to facilities. It is crucial to stress prevention, monitoring and reporting structures as well as efficient response procedures in order to act immediately when cases arise.

Awareness and Education on Plant diseases to the General population

Disease awareness and extension are among the top functions for managing plant diseases to

supporting future agricultural development. Given that plant pathogens to this present day present immense dangers to world food security, this analysis depicts how communities, farmers, and other stakeholders need to be knowledgeable in disease prevention and control. Awareness programs and any integrated educational crusades strengthen the people with the skills and knowledge to prevent, diagnose, and contain plant diseases unlike regular chemically based reactive measures that tend to spread the deadly pathogens across the farm. Among them is the need to raise awareness among farmers with regard to early signals and indicators of plant diseases. Another advantage of early pathogen identification is that farmers can manage disease early by removing the diseased plants, applying the right remedial measures or changing the farming practices in ways that reduces pathogen spread. Since extension services are largely involved in the delivery of training session, workshops and establishment of demonstration plots, they have got great responsibility of going to the field and ensuring that the intended target audiences get the information they need in their area of operation. These services assist the farmers to appreciate integrated disease management (IDM) that involves combination of chemical, biological and cultural methods of controlling plant diseases sustainably. However, raising awareness among farmers only is not enough; consumers should be well informed as well. Informed public attitude towards effects of plant diseases could be of benefit to food production and the environment by changing the behaviour of the public through promoting healthy food choice. Consumers can also participate in practices targeting sustainable agriculture and getting government's backing of policies for plant health and pest control. In addition, the cross-cutting partnership of several stakeholders such as Governments, Non-governmental organizations, academicians, and the private sector is crucial in order to magnify the effectiveness of the awareness creating efforts. Local and global organizations play a pivotal role in sharing information to create awareness to the world on new emerging pathogens in plants and therefore the need to manage them.

Conclusion

Thus, plant pathology as a scientific discipline is of utmost importance providing the means of

ensuring the safety of world nutrition and stable functioning of agriculture. Since plant diseases are still on the rise and causing decreased crop production and loss of species, it is important that the relationship between plants and pathogens are well understood. The molecular diagnostic tool, biotechnology and genomic implements show high potentiality for improving diseases diagnosis, resistance generation and pest control strategies. Also, the contracting approaches such as organic farming methods, use of bio control and under cultural methods were found to have environmentally friendly solution to diseases that would else call for chemical solutions. But the threats presented by plant diseases are increasingly dynamic factors such as climate change, globalisation, and pathogen resistance. In order to counter these problems, international collaboration and policy making and implementation are inevitable. The appearance of plant diseases creates the need for cooperation between International organizations, governments, and research institutions in setting up laws, as well as in exchanging information and collective strategies of combating the diseases. It will also afford a measure of protection from the spread of these diseases and will also assist in the protection of agriculture on a worldwide basis. Awareness creation or education, therefore, plays significant roles in empowering the farming populace and the consumers. Farmers can be educated on signs and indicators of early disease development, and on the significance of plant health for sustainable disease management and limited use of reactive approaches to pest control. Likewise, increasing consumers' awareness that they should buy products from sustainable agriculture, which is free from pathogens affecting the crop, will demand healthy produce. In the case of plant diseases therefore, solutions need to encompass scientific and technological advancement, policy formulation, multinational initiatives and awareness creation. There is the need to involve collective effort to work on sustainable management implication that will help to development resilience against plant diseases and to help provide food security as well as encouraging sustainable trade for the future of agriculture all over the world.

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