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Plant Diseases - A Global Challenge to Food Security

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Abstract

Plant disease outbreaks have caused massive food shortages and famines over the years. It poses a major threat to food security because they can damage crops, thus reducing the availability and access to food, increasing the cost of food. Each year an estimated 10-16 percent of global harvest is lost to plant diseases. Most of the crops are subjected to diseases both in the field and post-harvest by a number of major groups of pathogens. New plant diseases potentially threaten staple crops around the world giving rise to broad scale starvation in many parts of the globe. Additionally, disasters and transboundary diseases pose an enormous threat to food safety and security. Therefore, plant protection in general and the protection of crops against plant diseases in particular, have an obvious role to play in meeting the growing demand for food quality and quantity.

Introduction

Plants account for over 80 percent of the human diet while plant disease outbreaks have caused massive food shortages and famines over the years. Strange and Scott (2005) reported that 10-16 percent of global harvest is lost due to pest and plant diseases (Figure 1 and 2). All crops are subjected to diseases both in the field and post-harvest by a number of major groups of pathogens (fungi, bacteria, viruses, nematodes, protozoa, parasitic plants, etc). New plant diseases potentially threaten staple crops around the world giving rise to broad scale starvation in many parts of the globe. The status of global food security is alarming, *i.e.*, the balance between the growing food demand of the world population and global agricultural output. This imbalance is not new but has dramatically worsened during the recent decades. By the year 2050, food production will need to increase by more than 50 percent of 2012 production levels to meet demand. Globally, 820 million people suffer food insecurity and experience chronic hunger and undernourishment. The global human population is expected to reach 9.7 billion people by the year 2050. As the human population continues to grow, we face increasing challenges to ensure that people will have access to safe, nutritious and healthy food (Garcia *et al.*, 2020).

Food Security: An Indian Perspective

India has the largest number of undernourished people in the world. According to FAO estimates in "The State of Food Security and Nutrition in the World, 2018" report, about 14.8% of the population is undernourished in India. Nearly 47 million *i.e.*, 4 out of 10 children are affected by chronic undernutrition or stunting. India has been very successful in preventing famines but not more effectively combat undernutrition (Banik, 2016). Agricultural productivity in India is extremely low. According to World Bank figures,

cereal yield in India is estimated to be 2,992 kg ha⁻¹ as against 7,318.4 kg ha⁻¹ in North America. The composition of the food basket is increasingly shifting away from cereals to high value agricultural commodities like fish, eggs, milk and meat. As incomes continue to rise, this trend will continue and the indirect demand for food from feed will grow rapidly in India.

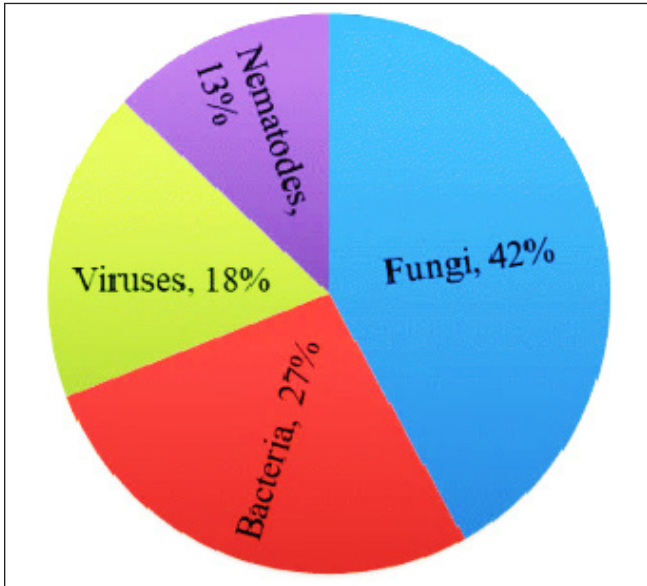


Figure 1: Crop losses by pests and diseases (%)

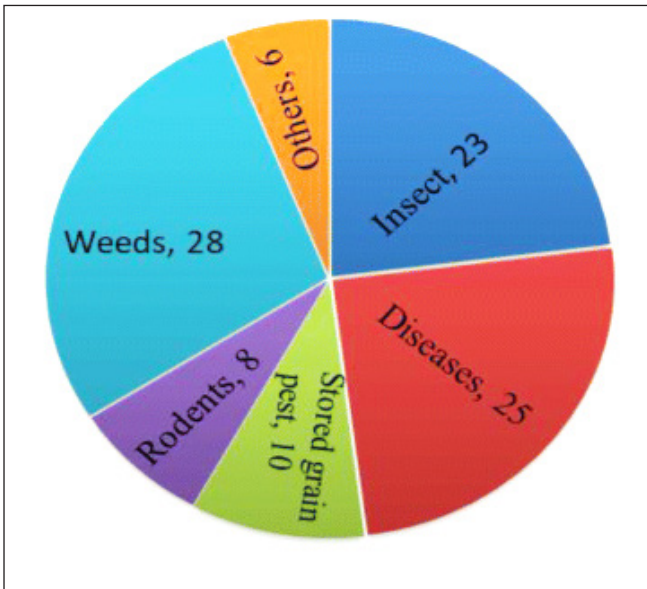


Figure 2: Crop losses by plant pathogens (%)

Measurement of Food Insecurity

Global Hunger Index

The global hunger index is a tool that measures and tracks hunger globally as well as by region and by country. The GHI is calculated annually by International Food Policy

Research Institute (IFPRI). In the GHI 2019 report, India ranked 102 among 117 countries. The GHI 2020 report has placed India at 94th position among 107 countries, much behind Bangladesh, Nepal and Pakistan.

Global Food Security Index

This index is a dynamic, quantitative and qualitative benchmarking model, constructed from 34 unique indicators, that measures these drivers of food security across both developing and developed countries. It considers the core issues of affordability, availability and quality across a set of 113 countries. India ranked 72nd globally and 16th in Asia Pacific region.

Food Loss and Wastage

Any food intended for human consumption that ultimately is never eaten by humans is considered under food loss and wastage. It has been estimated that one-third of global food is lost or wasted; entailing significant environmental, economic, and social costs. The economic costs of global food loss and waste (FLW) have been estimated to exceed \$1 trillion annually. Supplying food is resource intensive, involving 20 percent of global land, 70 percent of global water withdrawals, 32 percent of worldwide energy consumption, as well as other inputs, while generating solid waste, greenhouse gas (GHG) emissions, and other pollutants. Most of the food loss happens “near the farm” predominantly in lower-income countries and “near the plate” predominantly in higher income countries.

Threats to Global Food Security

Attaining food security will be the prime objective for any nation as it will be underlying foundation for other developments to take place. The major threats for global food security such as world population growth, the increased demand for food, ever-increasing food price, the disappearance of the variety of agricultural plant species, the increase in the area of scarcity water, and the limitation of the availability of land and the food losses and food waste. Majority of these threats are related to plant diseases and other agricultural menaces to a great extent. Global challenges of food security include an actively changing climate, pathogen evolution, increased risk of pathogen and pest invasions, a need for environmentally friendly vector and disease control inputs, slow development and release of resilient cultivars, slow technology transfer and adoption of new technologies at the field level.

Plant Diseases - A Threat to Global Food Security

The history of plant pathology is closely tied to plant diseases that have changed the course of human history. Plant diseases have caused severe famines

and related catastrophes in the past. Many historical and contemporary diseases are posing threat to modern agriculture and food security. Modern agricultural intensification has heightened the challenge of plant disease. Planting of vast swathes of genetically uniform crops, guarded by one or two inbred resistance genes, and partially protected from disease by the use of single target site antifungals, has hastened emergence of new virulent and fungicide-resistant strains. Finally, trade and transport of plants and plant products have further disseminated plant pathogens onto new hosts in hitherto unaffected areas of the world.

There are various factors which influence food security both directly and indirectly. The major among them are plant diseases, climate change, population growth, food loss and wastage (Figure 3).

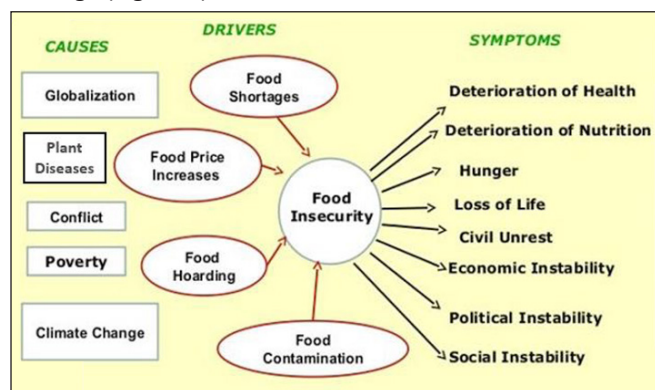


Figure 3: Factors in influencing Food Security

- Availability and primary food production.
- Availability through reliable import and storage.
- Access through the existence of reliable physical structure enabling food distribution.
- Access to food by consumers through sufficient purchasing power.
- Stability of food production over crop growing seasons and over successive years.
- Production of safe, nutritious food that meets desirable quality standards.

Reviews on crop losses caused by diseases commonly start with examples showing the dramatic and disastrous effects that plant disease epidemics have had historically. Epidemics may lead to disease injuries, which may lead to crop loss (damage) which, in turn, may lead to economic loss (Table 1 and 2).

Table 1: Crop loss estimates of major staple crops due to pests and diseases (Savary et al., 2018)

Crop	Estimated Yield Loss (%)	
	Global	Indo-Gangetic Plains
Wheat	21.47	16.57
Rice	30.03	40.86
Maize	22.51	41.14
Potato	17.22	21.00
Soybean	21.40	0.00

Table 2: Rankings of countries based on Global Food Security Index

Global ranking	Country	Overall score	Affordability	Availability	Quality & Safety
1 st	Singapore	87.4	95.4	83.0	79.4
2 nd	Ireland	84.0	90.5	76.8	87.7
3 rd	United States	83.7	87.4	78.3	89.1
4 th	Switzerland	83.1	83.8	84.3	78.2
5 th	Finland	82.9	84.1	78.6	91.8
72 nd	India	58.9	64.2	58.4	47.0

Examples of Plant Diseases being a Threat to Global Food Security

Many historical and contemporary diseases are emerging as threats to modern agriculture and food security (Table 3-7). These emerging diseases are not only important in global crop production, but also pose severe risks on a local level, especially on small farms in developing countries (Figure 4).

Emerging Phytobacterial Diseases in India

Bacterial diseases cause substantial yield losses to crop plants worldwide. In India the major bacterial diseases that cause considerable damages to crop plants include bacterial blight of rice (*Xanthomonas oryzae* pv. *oryzae*), bacterial blight of pomegranate (*Xanthomonas axonopodis* pv. *punicae*), bacterial wilt of solanaceous

Table 3: Crop loss estimates of major diseases in Rice (Savary et al., 2018)

Disease	Casual Organism	Estimated Yield Loss (%)	
		Global	Indo-Gangetic Plains
Sheath blight	<i>Rhizoctonia solani</i>	6.78	5.76
Blast	<i>Pyricularia grisea</i>	4.33	3.27
Brown spot	<i>Cochliobolus miyabeanus</i>	3.77	5.86
Bacterial blight	<i>Xanthomonas oryzaepv.oryzae</i>	2.72	8.51
Bacterial panicle blight	<i>Burkholderia glumae</i>	0.87	1.87
False smut	<i>Ustilaginoidea virens</i>	0.68	2.19
Sheath rot	<i>Sarocladium oryzae</i>	0.40	1.16
Rice tungro	Rice tungro virus (RTSV, RTBV)	0.27	0.43

Table 4: Crop loss estimates of major diseases in Wheat (Savary et al., 2018)

Disease	Casual Organism	Estimated Yield Loss (%)	
		Global	Indo-Gangetic Plains
Leaf rust	<i>Puccinia recondita f. sp. tritici</i>	3.25	4.25
Stripe rust	<i>Puccinia striiformis f. sp. tritici</i>	2.08	1.44
Spot blotch	<i>Cochliobolus sativus</i>	1.67	7.29
Stem rust	<i>Puccinia graminis f. sp. tritici.</i>	0.09	0.03
Wheat Blast	<i>Magnaporthe oryzae pv.triticum</i>	0.07	0.02
Fusarium seedling blight	<i>Fusarium graminearum</i>	0.002	0.011
Sclerotium foot and root rot	<i>Sclerotium rolfsii</i>	0.001	0.004
Loose smut	<i>Ustilago nuda f. sp. tritici</i>	0.0001	0.0004
Black Point	Alternaria, Fusarium and Helminthosporium species	0.002	0.011

Table 5: Crop loss estimates by major diseases in Maize (Savary et al., 2018)

Disease	Casual Organism	Estimated Yield Loss (%)	
		Global	Indo-Gangetic Plains
Fusarium stalk rot	<i>Fusarium verticillioides</i>	4.58	5.84
Northern leaf blight	<i>Exserohilum turcicum</i>	2.68	2.46
Fusarium ear rots	<i>Fusarium verticillioides</i>	2.38	4.52
Southern rust	<i>Puccinia polysora</i>	1.15	7.87
Common rust	<i>Puccinia sorghi</i>	0.75	2.46
Bacterial stalk rot	<i>Erwinia carotovora subsp. carotovora, Erwinia chrysanthemi pv. zeae</i>	0.64	1.18
Southern leaf blight	<i>Helminthosporium maydis</i>	0.55	2.46
Maize streak	<i>Maize streak virus (MSV)</i>	0.37	3.05
Banded leaf and sheath blight	<i>Rhizoctonia solani f. sp. sasakii</i>	0.20	3.62
Downy mildew	<i>Peronosclerospora sorghi</i>	0.14	2.53
Brown stripe downy mildew	<i>Sclerophthora rayssiae var. zeae</i>	0.04	1.12

Table 6: Crop loss estimates by major diseases in Potato (Savary et al., 2018)

Disease	Casual organism	Estimated Yield Loss (%)	
		Global	Indo-Gangetic Plains
Late blight	<i>Phytophthora infestans</i>	5.98	8.08
Brown rot	<i>Ralstonia solanacearum</i>	3.10	3.65
Early blight	<i>Alternaria solani</i>	2.59	2.08
Powdery scab	<i>Spongospora subterranea f. sp. subterranea</i>	0.94	1.06
Apical leaf curl	<i>Tomato yellow leaf curl virus (TYLCV)</i>	0.67	3.65
Common scab	<i>Streptomyces scabies</i>	0.46	0.47

Table 7: Crop loss estimates by major diseases in Soybean (Savary et al., 2018)

Disease	Casual organism	Global Estimated Yield Loss (%)
Soybean rust	<i>Phakopsora pachyrhizi</i>	2.96
Charcoal rot	<i>Macrophomina phaseolina</i>	1.31
White mould	<i>Sclerotinia sclerotiorum</i>	3.90

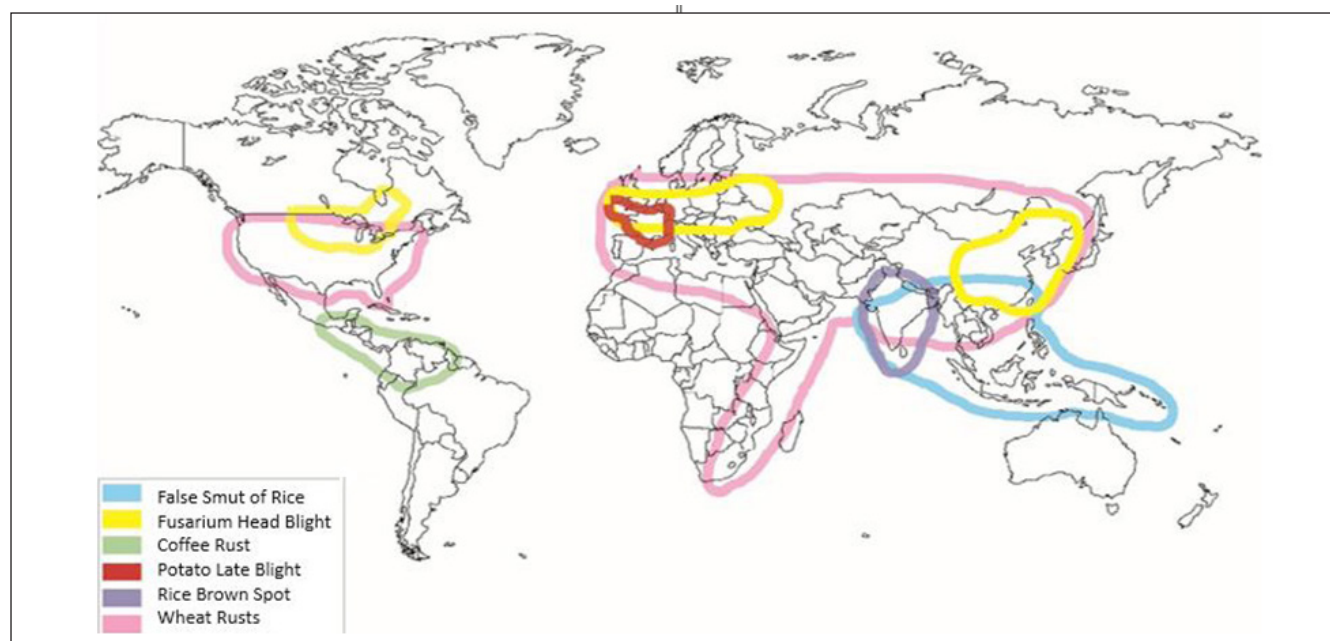


Figure 4: Graphical summary of important plant diseases

vegetables including tomato, capsicum, potato and eggplants (*Ralstonia solanacearum*), black spot of mango (*Xanthomonas citri* pv. *Mangiferae indicae*) and bacterial blight of cotton (*Xanthomonas citri* subsp. *malvacearum*). Besides, bacterial problems that has recently emerged as potential threat include panicle blight of rice (*Burkholderia glumae*), stalk rot of maize (*Pectobacterium chrysanthemi* var. *zear*).

Viral Diseases

Viruses are also a major group of plant pathogens that cause serious economic losses. Most of the emerging plant diseases are resultant of host interaction with viral

pathogens. Crop productivity losses by viral pathogens are between 3% and 7%. Changes in distribution of specific vector species can have an impact on the economic significance of the disease caused by the virus. Viral diseases such as Barley Yellow Dwarf Virus, Cassava Mosaic Virus and Maize Lethal Necrosis Virus have caused a serious implication on food security. Host plant infection by a single virus may lead to potential yield losses reaching maximally 90% as observed in potato. Bendi yellow vein mosaic disease (BYVMD) resulted in fruit yield reduction by as much as 96% if the crop is infected at early stage. In mungbean, yellow mosaic disease incidence in farmers' fields may be as high as 100%.

Ways to Mitigate the Losses

Solutions to the problems of plant disease come from many quarters. Exclusion of the pathogen through plant quarantine is the first line of defence and deserves more resources in relation to food security in developing countries. Other solutions include the exclusion, elimination or reduction of the pathogen's inoculum and development, for example by good cultural practices; intercropping and rotation; the judicious use of pesticides; exploiting the gene pool of the plant and its relatives in breeding programs (often the preferred approach where it is practical); understanding and combating virulence mechanisms of the pathogen; biological control (often difficult for plant pathogens); post-harvest protection; and improving plant performance through biotechnology.

International initiatives towards global food security include the High-Level Task Force (HLTF) on Global Food and Nutrition, formulation of the First Millennium Development Goal (MDG), the Zero Hunger Challenge, the Sustainable Development Goals (SDGs) also known as the Global Goals, were adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. Indian government has also initiated some policies towards agriculture and food security which include National Food Security Mission, Rashtriya Krishi Vikas Yojana, The National Food Security Act, Integrated Schemes on Oilseeds, Pulses, Palm oil and Maize, Pradhan Mantri Fasal Bima Yojana, and eNAM, 2016.

Future Perspectives

Developing sustainable food systems that include smallholder farmers, increasing food nutrition, ensuring food safety, ensuring a stable accessible food supply and decreasing food wastage and post-harvest

losses. Precise recognition of newly emerging pathogens and restricting their access and also understanding climate change to study host-pathogen interactions will help in effective disease management. Improving crop yields while maintaining environmental integrity and development of genetically enhanced plants will help to identify smarter ways to farm.

Conclusion

Providing food for the ever-increasing population in sufficient quantity and quality should be the current concern and the food produced should reach the plates of the needy. We have to protect our food so that it will help us survive. UN by setting up SDGs have laid a path to work towards a better future. Plant pathologists have a great role to play in ensuring food security to the future generations by managing plant diseases and reducing crop losses. Therefore, plant protection in general and the protection of crops against plant diseases in particular, have an obvious role to play in meeting the growing demand for food quality and quantity.

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