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Pandemics of People and Plants: Which Is the Greater Threat to Food Security?

As the world is gripped by the Coronavirus Disease 2019 (COVID-19) pandemic, plant epidemics are spreading silently, affecting crop yields and the global economy. Parallels have been drawn between the COVID-19 pandemic and the ongoing plight of plant diseases. While 7.4 million people have been infected by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the virus causing COVID-19, 822 million people, over 10% of the world's population, are currently facing food insecurity. Whereas the elderly and obese are at greater risk of fatality from COVID-19, it is the children and the malnourished who are at greatest risk from the consequences of plant diseases. There is no doubt that SARS-CoV-2 has had a negative impact on our food supply chain, causing shortages and increasing costs, yet plant pathogens have a significantly greater impact. Current hunger-related fatalities have reached 4 million this year, 10 times the number of COVID-19 fatalities. Unlike COVID-19, pathogen-related crop loss disproportionately affects food-insecure populations in developing countries (Savary et al., 2019). The developed world is spared the worst outcome of crop epidemics, namely famine.

Plant pathogens and pests are responsible for up to 40% of maize, potato, rice, soybean, and wheat crop yield losses worldwide (Savary et al., 2019). Plant diseases caused by bacteria, fungi, nematodes and viruses cost the global economy USD220 billion annually (Savary et al., 2019). Viruses make up almost half of the plant disease-causing pathogens, at an annual global cost of more than USD30 billion (Nicaise, 2014). Rice is cultivated in 100 countries, supporting nearly half the world's population, and is at risk from multiple vector-transmitted viruses, at a cost of USD1.5 billion annually. In 2019, the International Committee on Taxonomy of Viruses recognized 1484 plant viruses. Like animal viruses, plant viruses are grouped on the basis of viral genomic structure. There are 26 families of plant viruses, although only those infecting cash crops are investigated (Sastry et al., 2018). Belonging to the economically important DNA virus family, Geminiviridae*, Cassava mosaic begomovirus* infection results in an annual crop loss of 25 million tons. With half a billion people relying on this staple for a source of calories, epidemics of this virus directly lead to famine. As a member of Caulimoviridae*, Cacao swollen shoot badnavirus* (CSSV) has become endemic in Ghana, Nigeria, and Togo. West African cacao production accounts for 70% of the world's cacao supply. The loss of cacao plantations would devastate the local economy and lead to global cacao shortages. With 200 million trees dead due to CSSV infection, expensive eradication programs have been established to save the cacao industry (Nicaise, 2014). Members of the Bromoviridae, Closteroviridae, Luteoviridae, and Potyviridae families are all positive-sense single-stranded RNA viruses, like SARS-CoV-2, and are the most economically damaging group of plant viruses. Bromoviruses cause disease epidemics in fruits, vegetables, and animal feed. Citrus, an internationally high-value fruit crop, is at risk from *Citrus tristeza closterovirus*, a member of Closteroviridae that has caused the loss of 100 million citrus trees worldwide (Nicaise, 2014). Unfortunately, quarantine measures are only effective in areas with a low infection rate. The most widely distributed viral disease of cereals, *Barley yellow dwarf luteovirus*, of the Luteoviridae family, infects barley, maize, rice, oat, and wheat crops that sustain the world's population. *Potato leafroll polerovirus* is responsible for the annual loss of 20 million tons of potato, at a cost of USD100 million. The estimated cost for the management of the Potyviridae family member, *Plum pox potyvirus,* exceeds USD10 billion (Nicaise, 2014). The more famous Potyviridae family member, *Papaya ringspot virus,* devastated the papaya industry and could have led to the extinction of the species in Hawaii.

In response to the COVID-19 pandemic, the US government granted USD4.3 billion specifically for disease control, prevention, and global health programs. With its high rate of infection and severity of symptoms, it is not surprising that there is increased urgency to overcome and prevent future SARS-CoV-2 infection. COVID-19 symptoms range in severity from asymptomatic to multiple organ failure and death. Public-health policies, such as monitoring, screening, contact tracing, and quarantine, help limit the spread of SARS-CoV-2. However, comparable measures are expensive, labor-intensive, and time-consuming if applied to control the spread of plant pathogens. Asymptomatic carriers are the leading cause of infection propagation and disease spread, especially for fruit crops such as citrus, papaya, strawberry, and tomato in disease-free regions (Kado, 2016). Conventional methods, such as biological (natural predators of the vectors) and chemical (pesticide application), have been utilized for decades, although they do not eradicate the pathogens. Modeling predictions based on environmental conditions, vector proliferation, and viral-genome evolution, could forewarn new disease emergence. Drone surveillance, self-monitoring, and reporting could control both human and plant diseases. But pandemics occur unexpectedly, and strategies to combat emerging infectious agents rarely prevent outbreaks. Thus, to prevent future outbreaks, awareness, preparation, and long-term funding support are required. However, there are large funding discrepancies between human and crop diseases. The 2020 US budget for Human Immunodeficiency Virus (HIV) research (USD2.6 billion) is USD150 million more than the entire budget for agricultural research.

Vaccination is economically sound and less labor-intensive than screening and quarantine measures. Although plants do

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not have an adaptive immune system like that of humans, the expression of weaker related viruses or viral proteins leads to disease resistance. Innate immunity in plants, as in humans, protects against pathogens. Antiviral Resistance (R) genes prevent systemic spread by eliciting programmed cell death, and RNA silencing prevents viral replication (Soosaar et al., 2005). Traditional methods of breeding and grafting can confer such pathogen resistance, but in response to the *Papaya ringspot virus* epidemic, the first virus-resistant papaya was obtained through bioengineered expression of viral protein, successfully demonstrating plant vaccination (Ferreira et al., 2002). Since then, successful RNA silencing-based genetic resistance has been demonstrated in bean, papaya, pepper, plum, potato, squash, and tomato, although the application of biotechnology is underutilized (Khalid et al., 2017). Bioengineering pathogen resistance could control plant pandemics, reduce yield loss, and promote food security; however, limited funding and negative public opinion about genetically modified crops are obstacles to their development and subsequent cultivation and consumption. Eradication of emerging or reemerging infectious diseases requires fast affordable testing and universal vaccination programs. Bioengineered expression of antiviral proteins in *Nicotiana benthamiana* could provide fast and inexpensive diagnostic reagents and vaccine candidates against SARS-CoV-2 (Capell et al., 2020). With this in mind, perhaps a positive outcome of COVID-19 could be a change in public attitude toward the application of biotechnology to fight diseases of both plants and people.

The COVID-19 pandemic has influenced our way of life and emphasized the need to review and prepare for future outbreaks. Food shortages and increasing costs also highlight the fragility of our food supply chain. To avoid further disruption, produce collection from growers and redistribution strategies to the consumer need to be developed when commercial operations are unavailable. Approaches to limit the spread of SARS-CoV-2, including business closures and global travel restrictions, have triggered an economic depression. This will lead to reduced funding, disproportionately affecting agricultural research, resulting in fewer investigators and international collaborations and ultimately exacerbating plant disease and crop loss. The International Year of Plant Health has been eclipsed by COVID-19. This year was meant to raise awareness of the lack of resources and funding to combat plant diseases and to promote global collaboration and engagement in support of plant health. To prevent the negative effects of COVID-19 on plant disease research, these aims should be adhered to and supported. The developed world is spared the consequences of crop damage caused by plant pathogens, and as a result, policy makers and the public perceive less urgency to invest in new methods to protect against and treat crop infection. Funding for crop disease research continues to decline, partly due to the sporadic nature of outbreaks. In the coming decades, however, population growth will demand increased agricultural output, while we battle against environmental changes that cause drought, flooding, and exacerbated plant disease. Without increased visibility and funding, current initiatives toward the development of resistant crops cannot keep up with the number of infections threatening global food production.

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