COVER STORY

INTERNATIONAL YEAR OF
PLANT HEALTH
2020

International Year of Plant Health

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2020 is the International Year of Plant Health. Even during the COVID-19 pandemic, and the subsequent lockdown, it is the supply of fruits and vegetables that keeps us going. It is incumbent on us therefore that in the International Year of Plant Health we pledge to keep the plants and crops around us healthy and free of diseases.

IN true terms, 2020 has become a year of flourishing plants. Just look out of your window or walk to your balcony and feel the green. The leaves that were covered with layers of dust are now smiling wide. The trees that were dying because of pollution and heat are now breathing tight. The depressing surroundings have become lively.

Yet, the plants do not seem to be so relaxed. Just as we watch them, they are also watching us. They can make out the fear in our heads and the panic on our faces. And they are wondering what if they also get attacked by some virus-like the coronavirus. Even though plants are used to virus attacks, and very well know the pain and loss caused by a virus.

Just like a virus has set the reset button of our lives, viruses attack these plants too. We need to know about these plant viruses because we are surrounded by plants, eat these plants, use them and abuse them to the hilt. But are the viruses attacking humans and plants the same? Let's start from the basics and proceed to the complex.

By definition, a virus is an infective agent that typically consists of a nucleic acid molecule in a protein coat, is too small to be seen by light microscopy, and is able to multiply only within the living cells of a host. A virus is a submicroscopic infectious agent that replicates only inside the living cells of an organism. Viruses can infect all types of life forms, from animals and plants to microorganisms, including bacteria.

What is a Plant Virus?

Like other viruses, plant viruses are also composed of a nucleic acid (genome), which is encapsidated by a protein coat. In addition, particles of some plant viruses, like members of the genus *Tospovirus*, are enveloped by an outer membrane containing lipids and proteins. A similar lipid envelop is also found in Coronaviruses, though they belong to different families. In India, two families of viruses, namely Geminiviridae and Potyviridae, are the major killers of agricultural crops.

The amount and arrangement of the proteins and nucleic acid of viruses determine their size and shape. There is a great variation in the size and shape of the plant viruses, ranging from 17 nanometres to 2000 nanometres in size. Shapes of viruses are predominantly of two kinds: rods or Filaments,

The lockdown has breathed life into plants and trees



Plants are just as susceptible to viral infections as other living organisms

like a rigid rod, flexuous rod, isometric, bullet shape, twin icosahedral, etc. Majority of the plant viruses have single-stranded positive-sense RNA genome.

Besides, there are plant viruses with a genome composed of single-stranded negative-sense RNA, double-stranded RNA, single-stranded DNA and double-stranded DNA. Many of the plant viruses have a multi-segmented genome, which is either encapsidated in different particles or within a single particle. The plant virus genome codes for proteins essential for their replication, cell-to-cell movement, and encapsidation.

Apart from these essential protein-coding genes, genomes of many plant viruses additionally code for proteins necessary for insect transmission and suppressors of RNA silencing to overcome the plant defence. Many plant viruses are associated with satellite DNA or RNA molecules, which increases their virulence and host adaptability.

Symptoms caused by tomato spotted wilt virus

How do Viruses Attack Plants?

Plants are just as susceptible to viral infections as other living organisms. Plant viruses can not directly penetrate the host cell as plants have a cell wall to protect their cells. Till now there is no evidence that a receptor of cell wall allows the plant virus to enter host cell through endocytosis, which is very common for human and animal viruses.

So, a wound is necessary for a plant virus to enter a plant cell. The wound may be created by weather, insects, animals, or even human activities during agricultural operations. Once a plant gets a viral infection, it spreads through different vectors like insects, nematodes, fungi which attack plants. More than 70 per cent of known plant viruses are transmitted by insects, the majority belong to the order Hemiptera, which includes aphids, planthoppers, leafhoppers, bugs, etc.

Many viruses may pass to new offspring through propagating materials of plants, pollen, etc. Upon entering into the plant cell, plant viruses translate their proteins, replicate their genome and move from one cell to another cell. During these processes plant viruses continuously exploit different host proteins, interact with different proteins and thus regulate different cellular pathways. Such intense interaction ultimately leads to the development of abnormalities or symptoms.

What Happens in a Virus Attack?

One of the characteristics of viruses is that they mutate very fast, not on their own, but inside the host body, infecting not only one cell or one plant – the emerging viruses infect newer hosts and lead to an epidemic like situation. The viruses can turn out to be deadly for any living form. They have the negative ability of destroying complete crop production, species and even genres of plants.

Some viruses act friendly with plants, equilibrate themselves with plant ecosystems and ruin agriculture. The *Tospovirus* of tomato is an example of a friendly virus destroying the tomato crop completely. Viruses, in general,

affect plant growth, production and productivity. In a virus attack, plants don't get proper nutrition as it is all taken by the virus. The plants feel stranded and unassisted. Just like in humans and animals, viruses affect the plant's respiratory system badly and also lead to tension in plants.

Can Virus Attack on Plants be as Deadly as Coronavirus?

Just like all other viruses, plant viruses are obligate pathogens that depend on their hosts to survive. So, no viruses deliberately kill their host as that will not be beneficial for their own survival. Except a few plant viruses like *Tospovirus*, which are believed to be of insect origin, plant viruses generally do not kill any plants. They weaken the plant immunity, reduce the plant growth, vigour and thus reduce yield and deteriorate the quality of the produce.

If a severe virus infection occurs in an early stage of plant growth the plant may not be able to produce any product. Due to weak immunity, or when attacked by other pathogens too, the plants ultimately get killed. There are many plant viruses belonging to the genus *Begomovirus*, *Tospovirus*, *Illarvirus*, which are as severe as coronavirus, where the infection spreads like wildfire through insects within weeks and almost no yield can be obtained from the entire field.

How to Tackle the Viruses?

With our recent experience, we can fathom that a virus can't be handled even with care. For any farmer, the only solution to get rid of viruses in plants is to burn and remove the affected plant – breaking the chain and establishing social distancing are the keys to prevent a virus attack. And so, removing or burning the affected plant for saving other plants is the idea. Else, farmers can spray insecticides or pesticides to save the plants from any kind of attack by insects and pests. The least that can be done is changing agricultural practices, which most of the times is not very feasible.

But these are not long term solutions. Dr Sunil Mukherjee, a senior scientist in the field of Plant Molecular Biology, Indian National Science Academy emeritus scientist who retired from the International Centre for Genetic Engineering and Biotechnology, and who made tomato transgenics to resist tomato leaf curl viruses, is of the opinion that traditional methods are not effective and most of the times turn out to be ecologically unfriendly. He emphasises that plants can sense pain, death-pang, etc. but at the same time, plants also recover from viral infection because of RNAi-considerations. It is one of the recent therapeutic techniques.

In terms of saving plants from virus attack, RNAi and CRISPR-Cas methodologies are the most preferred ones. In terms of silencing a gene, the primary difference is that RNAi 'knocks-down' a gene while CRISPR/Cas 'knocks-out' a gene. RNAi is widely used by researchers to silence genes in order to learn something about their function. But, if you want to completely silence a gene, CRISPR technology is better.

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Dr Mukherjee explains in detail the RNAi and CRISPR/Cas methodologies. He says plants possess immunological factors like proteins called RNAi factors which help plants defend themselves against plant viruses. In places like Hawaii, USA, China, Latin America, etc., RNAi-based transgenic plants are in commercial cultivation to minimise viral pathogen-induced losses. As transgenics are not liked by regulatory considerations, application of dsRNA (of viral sequences) spray is a popular method to adopt for plant protection. However, the stability of the externally applied dsRNA is a big question and nano-carrier-tagged dsRNAs are used for sustained and prolonged release of dsRNA. So, research is focused on finding nano-carriers that are cheap and non-toxic to plants.

CRISPR-Cas is the most recent technique in the armoury of antiviral strategies. The guided Cas9 enzyme is generally used against DNA viruses like geminiviruses, caulimoviruses, banana streak viruses, etc. Similarly, Cas13 is used against RNA viruses like *Turnip Mosaic Virus* (TuMV), *Potato Virus Y* (PVY), *Rice Stripe Mosaic Virus* (RSMV), *Southern Rice Black-streaked dwarf Virus* (SRBSV), etc. These are applications of CRISPR-Cas on viral genome directly.

Conversely, hosts can also be manipulated as plants harbour genes known as the Sensitive (S) genes which sensitize plants towards the pathogens. The elimination of S genes paves the way for achieving virus-resistant plants. Papaya can be cured of *Papaya Ring Spot Virus* (PRSV) in this manner. Both RNAi and CRISPR-Cas methodologies suffer from attack on unwanted neutral or healthy genes, technically called "off-target" effects. However, a great deal of research is being carried out to get rid of such effects and to make plants virus-free for safe human consumption.

Nucleic acid-based or antisera based detection kits are known for a few of the viruses. But we lack large scale screening systems for viruses. DNA-microarray is a technique that enables massive screening. Using this technology, we will be able to know the nature of emerging viruses in a short time with relatively moderate resources. This technology

gives us the surveillance power over prevailing viruses and if we add virulence information, we can build mathematical models to predict which crop will be in danger by what kind of viral pathogens and when. Metagenomics is also a recent technique for large scale screening but the functionality of the viruses remains unknown by the method.

Can Plant Viruses be Cured?

Once a plant gets infected by a virus there is no way to cure that plant. Sometimes due to the plant's own defence mechanism symptom recovery is observed but this happens rarely. Though plants do not have an antibody mediated immune response system like animals and humans, they possess a general defense system called RNA silencing, which detects and degrades viral RNAs or viral transcripts.

To overcome this defence, the majority of plant viruses encode a protein called suppressor of RNA silencing, which inactivates the host defence. Depending on the plant defence and viral pathogenicity the plant's response to the infection may range from a symptomless condition to severe disease. There is no chemical or drug available till now to cure an infected plant. With proper nutrition and supplement of some essential minerals, in few cases severity of symptoms can be reduced but under severely infected condition no cure is possible. However, prophylactic application of different molecules (e.g. dsRNA) has shown promising results in preventing plant virus infection.

How are Plant Viruses Managed?

The best way to manage a plant virus infection is to protect the plant from getting infected as there are no antiviral compounds available to cure plants with viral diseases. The first step for management of the virus is to identify the virus, understand its transmission behaviour and survival.

Different preventive measures like use of certified virus-free seed or vegetative propagules, elimination of the weeds and other surrounding plants that may harbour virus, modification of planting and harvesting practices, and intercultural operations are important cultural practices those can greatly reduce the risk of viral infection in plant. If the virus is transmitted by a vector, control of the vector through judicious use of chemical or mulching may be effective.

The most important aspect of plant virus management is to develop crop varieties with resistance. The resistance may be incorporated through conventional breeding from natural plant sources or may be derived from the virus through transgenic development. Recently topical application of dsRNA and gene-editing technology has shown promise for management of viral diseases but these studies are still in their infancy.

Can Plant Viruses Jump to Humans?

Generally, viruses evolve with their host and a great specificity exists with the virus and their hosts. However, for viruses, it is not uncommon to switch the host kingdom. Since humans depend on agricultural crops, plant viruses can enter the human body through virus-infected foods, which is evidenced from the fact that many stable plant viruses have been detected in human feces.

If a plant virus could break down the host specificity and is able to multiply in an animal, this multiplication could remain unnoticed if it is not associated with a specific symptom and if there is no further transmission to other animal. Certainly, till now there is no evidence that plant viruses cause diseases in humans and other animals. A report has shown that a plant virus, Pepper Mild Mottle Virus (PMMoV), found in many pepper-based products could be detected in human body but the symptom associated with the illness cannot be correlated.

Upon experimental exposure plant viruses can be detected in mammals and human samples, and there is also evidence of immune responses to plant viruses in animals and humans. There is no rigid rule that plant virus can not break the barrier of their host kingdom and invade humans or animals. There are many plant viruses, like tospoviruses, reoviruses, rhabdoviruses, which can replicate in their insect host. So, if a plant virus can infect insects it may also be not impossible to infect humans. Although till now there is no such evidence.

The best way to manage a plant virus infection is to protect the plant from getting infected (Photo: www.farmmanagement.pro/)

Many human-infecting viruses and plant-infecting viruses belong to the same family with similar genome organisation. For instance, viruses of the family *Reoviridae*, *Phytoreovirus*, *Fijivirus* and *Oryzavirus* infect plants while the rotavirus, a major cause of gastroenteritis in humans, also belongs to this family. Similarly, under the family *Rhabdoviridae*, which includes rabies virus infecting humans and animals, there are also plant and insect infecting viruses like *Cytorhabdovirus, Nucleorhabdovirus, Dichorhabdovirus* and *Tenuivirus*.

Similarly, plant and insect infecting genus *Tospovirus* belongs to the family *Bunyaviridae*, which also possesses Hantaan virus and Toscana virus infecting humans. Although in those cases viruses have similar genome structure and the genes involved in viral genome replication and expression are conserved between plant and animal viruses, but the genes concerned in virus-host interactions are not the same. For thousands of years, humans have been eating plant products but till now there is no evidence to suggest a plant virus as a human pathogen.

Dr Anirban Roy, Principal Scientist in the Advanced Center for Plant Virology, Division of Plant Pathology at Indian Agricultural Research Institute, firmly states that plant viruses are not less important than human viruses. In the case of humans, we are looking at the impact of a virus on an individual, while in the case of plants we measure the impact on entire human populations. Humans can protect themselves by quarantine, can plants do so? Being immobile it has to get infected in a field if infection starts.

Plant virus disease has many fold impact starting from quality and quantity of yield, to business trade. Estimating the loss caused due to plant viruses is very complicated and often figures are not available for all the diseases. Some reports indicated that a range of viruses is responsible for an estimated $60 billion in crop losses worldwide each year. A few specific examples, like yield loss caused by barley yellow dwarf virus and potato leafroll virus of a value of £40-60 million per year in the United Kingdom, and yield losses of moong bean, urad bean, cowpea, and soybean by yellow mosaic viruses in the tune of US$300 million in India, definitely show the importance of plant viruses in human society.

Historically, a virus disease that causes a colour variegation symptom in the tulip flower caused the Dutch economy to collapse during the 17th century as such flowers were considered as a gift of god and abnormal high prices were paid for them.

An Initiative for Plants to Flourish

The story of the International Year of Plant Health (IYPH) began in 2012 at the Stockholm Conference which decided that a year would be devoted to plants. The United Nations General Assembly took charge and raised this issue globally. It can be marked as a golden opportunity to raise global awareness on protecting plants. Considering plant health as priority can help end hunger, reduce poverty, protect the environment, and boost economic development. All these are interlinked.

The theme of the International Year of Plant Health 2020 is 'Protecting Plants, Protecting Life'. IYPH is a once in a lifetime opportunity to raise global awareness on how protecting plant health can help end hunger, reduce poverty, protect the environment, and boost economic development. The focus is on preventing the spread of pests and diseases because they have the greatest impact on our crops, our environment and our way of life.

Dr Trilochan Mohapatra, Director General of the Indian Council of Agricultural Research, believes that investing in plant health research is necessary to withstand plant diseases, reduce food insecurity, feed the growing population, and make our planet more sustainable. All national governments and international organisations should join hands to create massive awareness across the globe. He strongly recommends massive awareness campaigns to educate travellers moving in and out of the country to be cautious while bringing plants or plant products across borders and to spread the key messages of healthy plants responsible for healthy living.

Healthy plants are vital to sustainable and profitable crop production and to the quality and cost of the nation's supply of food, fuel, and fibre. According to the Food and Agriculture Organization (FAO), 40% of food crops are lost to plant pests and diseases annually. This leaves millions of people without enough food to eat and seriously damages agriculture – the primary source of income for poor rural communities.

Health is also critical to plants used for ornamentals, natural resources, and animal feed. Plant health is increasingly under threat. Climate change and human activities have altered ecosystems, reducing biodiversity and creating new niches where pests can thrive. At the same time, international travel and trade, which have tripled in volume in the last decade, can quickly spread pests and diseases around the world causing great damage to native plants and the environment.

What We Mean for Plants?

Plants need water, light, temperature and nutrients to survive. But today there is increasing threat from us the humans – climate change, pests and diseases – are all outcomes of the kinds of lifestyles we have chosen to adopt.

Senior Science Communicator Mr Kuldeep Sharma opines that "We are the guests of the plants on the earth." Associated with the oldest and longest-running show devoted to agriculture and focussed on welfare of our farmers, *Krishi Darshan*, since 1982, Mr Sharma stresses that IYPH is important because we have misused plants over decades and don't understand the importance even after continuous reminders.

Even during the COVID-19 pandemic, and the subsequent lockdown, it is the supply of fruits and vegetables that is keeping us going. It is incumbent on us therefore that in the International Year of Plant Health we pledge to keep the plants and crops around us healthy and free of diseases.

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