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AgriTech Today

AGRICULTURE AND ALLIED SCIENCES E-MAGAZINE

Volume 1, Special Issue (SEP, 2023)

SPECIAL ISSUE

PLANT PATHOLOGY

GUEST EDITOR

PRAVALLIKA SREE RAYANOOTHALA

AgriTech Today

Volume 1, Special Issue
September, 2023

Publisher
Valmiki Sahitya Sampada
Harthikote Post
Hiriyur, Chitradurga Dist.,
Karnataka - 577545

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From the Editor-in-chief's Desk

I am happy and proud to announce the release of the Special issue on Plant Pathology for the month of September, 2023.

Plant pathology plays a crucial role in agriculture by helping to safeguard crop health and maximize agricultural productivity. It identifies and manages diseases caused by pathogens such as fungi, bacteria, viruses, and nematodes, preventing crop losses that could threaten food security. It aids in the development of disease-resistant crop varieties through breeding and genetic engineering, reducing the need for chemical pesticides. Plant pathologists contribute to sustainable farming practices by promoting integrated pest management strategies, reducing environmental impacts. They provide essential diagnostic services to farmers, enabling early disease detection and timely intervention. Plant pathology research enhances our understanding of plant-microbe interactions, leading to innovative solutions for improving crop resilience and overall agricultural sustainability.

This issue, was specially curated to include the topic related to Plant Pathogens and diagnostics, Pathogen interaction with host, vector and other, microbes, Ecology and epidemiology of plant diseases, recent approaches in plant diseases management, secondary metabolites and plant disease response, industrial microbiology and mushroom artificial intelligence and IT in Plant Protection etc. It gives me great pleasure to inform you that we have curated and finalized 22 articles for publication in this issue.

I extend my heartfelt gratitude to the Guest Editor Dr. Pravallika Sree Rayanoothala for her contribution as Guest Editor for this Issue and also for the dedicated editorial team and the talented authors for their invaluable contributions in bringing this issue to fruition. Your efforts have played a pivotal role in making AgriTech Today Magazine a source of enlightenment and knowledge in the agricultural domain.

Editor-in-chief

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GUEST EDITOR'S MESSAGE

I am delighted to welcome you to this special issue of Agritech Today Magazine, which delves deep into the fascinating world of Plant Pathology. In this edition, we embark on a journey through the intricate and critical aspects of plant diseases, their management, and their profound impact on the agricultural landscape.

Plant pathology, often referred to as the guardian of our crops, plays an indispensable role in safeguarding our global food security. This special issue is a tribute to the dedicated researchers, scientists, and experts who tirelessly work to unravel the mysteries of plant diseases and devise innovative solutions to combat them.

Throughout these pages, you will find a rich tapestry of knowledge, insights, and discoveries. Our esteemed contributors have shared their expertise on a wide range of topics, from the latest advancements in disease detection and diagnostics to sustainable strategies for disease management that promise to reshape the future of agriculture. Whether you are a seasoned professional in the field or a curious enthusiast, there is something here for everyone.

We extend our gratitude to the authors, reviewers, and all those who have contributed to this issue. Their dedication to advancing the field of plant pathology is truly commendable. We also thank you, our readers, for your continued support and engagement with Agritech Today Magazine. Your curiosity and commitment to agricultural innovation drive us to continually explore new frontiers.

In closing, we invite you to immerse yourself in the wealth of knowledge within these pages. We hope this special issue inspires you to be a part of this critical journey, and together, we can cultivate a healthier, more resilient world.

Happy Reading!

Sincerely,

(Pravallika Sree Rayanoothala)

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Diseases of Rice and Their Management

Ram R. M. [1], Patel S. S[1], Singh A. K. [1], Kumar V. [1*], Chandola, J.C.[1] and Regar, K. L. [1]
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Rice (*Oryza sativa* L.) is considered as one of the most important staple food crops of the world and nearly half of the world's population is dependent on it. The crop plays a pivotal role in global food security. Since rice is grown in wide area across the globe, it is prone to get attacked by several plant pathogens such as, fungi, bacteria, viruses and nematodes. Among the major diseases rice blast, bacterial leaf blight, bacterial leaf streak, sheath blight, sheath rot, stem rot, false smut and rice tungro virus are economically important and they cause huge monetary losses. In the recent years, due to alteration in the global temperature and climate change, various minor diseases appeared as major ones and thus posing a threat to food safety and security. The various management practices includes use of resistant varieties, cultural practices, biological and chemical control. All these strategies have varied degrees of success in managing rice diseases. But their integration could be more effective and successful management of plant disease in rice. The various diseases in rice includes:

Blast: ***Pyricularia oryzae***

Symptoms

- Above-ground parts of the rice plant (leaves, nodes and neck) are attacked by the fungus
- Initial symptoms are white to grey-green lesions or spots with brown borders
- Small specks originate on leaves - subsequently, enlarge into spindle-shaped spots (0.5 to 1.5 cm length and 0.3 to 0.5 cm width) with an ashy center.
- Older lesions are elliptical or spindle-shaped and whitish to grey with necrotic borders. Several spots coalesce to form big irregular patches.
- Lesions on the neck are greyish brown and cause the girdling of the neck and the panicle to fall over.
- If an infection of the neck occurs before the milky stage, no grain is formed, but if the infection occurs later, grains of poor quality are formed.

Fig. 1. Type of blast a) Leaf blast b) Collar blast c) Nodal blast

Management

Cultural methods

- Planting resistant varieties against the rice blast is the most practical and economical way of controlling rice blast.
- Use of tolerant varieties (CO 47, CO 50, ADT 36, ADT 37, ASD 16, ASD 20, ADT 39, ASD 19, TPS 3, White ponni, ADT 44, IR 64 and IR 36)
- Avoid excess N - fertilizer application
- Apply nitrogen in three split doses.

Chemical methods

- Thiram or captan or carboxin or carbendazim at 2 g/kg of seeds.
- Carbendazim or Tricyclozole at 2 g/lit of water for 1 kg of seed.
- Soak the seeds in the solution for 2 h

- Drain the solution, sprout the seeds and sow in the nursery bed.
- Treat the seeds with talc-based formulation of *P. fluorescens* (Pf1) @ 10g/kg of seed and soak in 1 litre of water overnight.
- Decant the excess water and allow it to sprout the seeds for 24 h and then sow.

Fig. 2 i) Wavy margin ii) Bacterial ooze

Bacterial leaf blight: *Xanthomonas oryzae pv. oryzae*

Symptoms

- Water-soaked to yellowish stripes on leaf blades or starting at leaf tips with a wavy margin
- Leaves with undulated yellowish white or golden yellow marginal necrosis, drying of leaves back from tip and curling, and leaving mid rib intact are the major symptoms.
- The appearance of bacterial ooze that looks like a milky or opaque dewdrop on young lesions early in the morning
- Severely infected leaves tend to dry quickly
- Loss in grain yield may be up to 60%.

Favourable conditions

- Presence of weeds
- Presence of bacteria in the rice paddy and irrigation canals
- Warm temperature (25-30° C), high humidity, rain and deep water.
- Irrigation water and splashing or windblown rain can disseminate the bacterium from plant to plant.
- The use of trimming tools for transplanting and by handling during transplanting can also trigger new infections.

Management

Preventive method

- Seed treatment - seed soaking for 8 hours in Agrimycin (0.025%) and wettable Ceresan (0.05%) followed by hot water treatment for 30 min at 52-54 ^{o}C;
- Seed soaking for 8 hours in Ceresan (0.1%) and treat with Streptocyclin (3g in 1 litre);
- Spray neem oil 3% or NSKE 5%

Chemical methods

- Spray Streptomycin sulphate + Tetracycline combination 300 g + Copper oxychloride 1.25kg/ha. If necessary repeat after 15 days.
- Application of bleaching powder @ 5 kg/ha in the irrigation water is recommended at the kresek stage.
- Foliar spray with copper fungicides alternatively with Streptocyclin (250 ppm) to check secondary spread.
- Two sprays of Copper hydroxide 77 WP@1.25 kg/ha 30 DAP & 45 DAP

Bacterial leaf streak: ***Xanthomonas campestris p.v. oryzicola***

Symptoms

- Fine translucent streaks appear between the veins of the leaf are the first symptoms.

- The lesions enlarge lengthwise and advance over larger veins laterally and turn brown.
- On very susceptible varieties a yellow halo appears around the lesions.
- On the surface of the lesions, bacteria ooze out and form small yellow band-like exudates under humid conditions.

Fig. 4 Apprance of yellow leaf and identification of RTVP & RTSV under microscope

Favourable conditions

High relative humidity (83-93%) or dew during morning hours for 2 to 3 hours

Management

- Affected stubbles are to be destroyed by burning or through ploughing.
- Judicious use of nitrogenous fertilizers. .
- Soak the seed in Streptocycline (250 ppm) followed by hot water treatment at 52 ^{0}C for 30 minutes eradicates seedling infection.

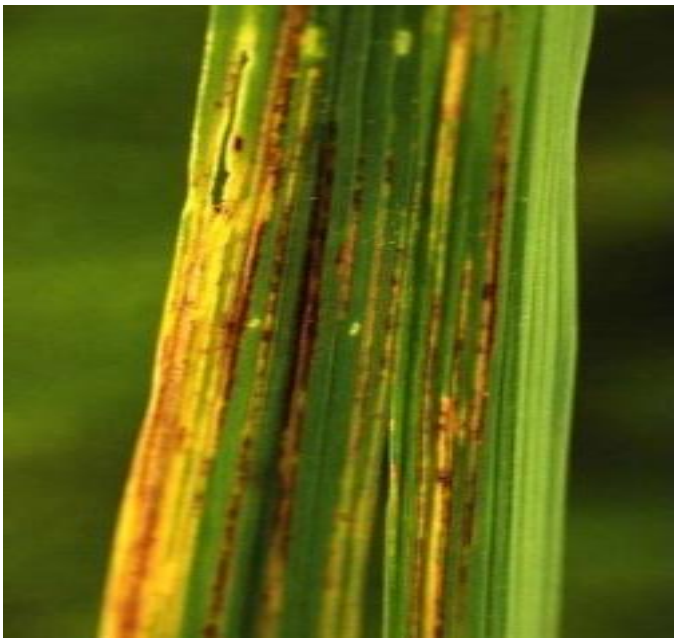

Fig. 3 Bacterial leaf streak

- Spray Streptocycline (250 ppm) along with copper oxychloride (0.3%)

Rice tungro virus: *Rice tungro bacilliform virus* **(RTBV) and** *Rice tungro spherical virus* **(RTSV)**

Symptoms

- Plants affected by tungro exhibit stunting and reduced tillering. Leaves become yellow or orange-yellow, and it may also have rust-colored spots.
- Discoloration begins from the leaf tip and extends down to the blade or the lower leaf portion
- Most panicles are sterile or partially filled grains
- Tungro virus disease affects all growth stages of the rice plant specifically high at the vegetative stage.

Favourable conditions

- Presence of the virus sources.
- Presence of the vector.
- Age and susceptibility of host plants.
- Synchronization of the three above factors.
- All growth stages of rice plant specifically the vegetative stage

Management

Trap methods

- Light traps are to be set up to attract and control the leaf hopper vectors as well as to monitor the population.

- In the early morning, the population of leafhopper alighting near the light trap should be killed by spraying/dusting the insecticides. This should be practiced every day.

Cultural methods

- Planting of resistant varieties against tungro virus disease is the most economical means of managing the disease.
- Among the cultural management practices, adjusting the date of planting is recommended.
- Plouging and harrowing the field to destroy stubbles right after harvest

Chemical methods

- Leaf yellowing can be minimized by spraying 2 % urea mixed with Mancozeb at 2.5 gm/lit.
- Green leaf hoppers as vectors are to be controlled effectively in time by spraying.
- Vegetation on the bunds should also be sprayed with the insecticides. Maintain 2.5 cm of water in the nursery and broadcast anyone of the following in 20 cents Carbofuran 3 G 3.5 kg (or) Phorate 10 G 1.0 kg (or) Quinalphos 5 G 2.0 kg.

Sheath Blight: ***Rhizoctonia solani***

Symptoms

- The fungus affects the crop from tillering to heading stage.
- Initial symptoms are noticed on leaf sheaths near water level.
- On the leaf sheath oval or elliptical or irregular greenish grey spots are formed.
- As the spots enlarge, the centre becomes greyish white with an irregular blackish brown or purple brown border.
- Lesions on the upper parts of plants extend rapidly coalescing with each other to cover entire tillers from the water line to the flag leaf.
- The presence of several large lesions on a leaf sheath usually causes death of the whole leaf, and in severe cases all the leaves of a plant may be blighted in this way.
- The infection extends to the inner sheaths resulting in death of the entire plant.
- A yield loss of 25% was reported if the flag leaves are infected.

Favourable Conditions

High relative humidity (96-97 per cent), high temperature (30-32 ^{0}C), closer planting and heavy doses of nitrogenous fertilizers.

Fig.5 Sheath blight disease in Rice

Management

Cultural methods

- Apply FYM 12.5 t/ha or green manure 6.25 t/ha to promote antagonistic microflora
- Avoid excess doses of fertilizers.
- Adopt optimum spacing.
- Eliminate weed hosts.
- Avoid flow of irrigation water from infected fields to healthy fields.
- Deep ploughing in summer and burning of stubbles.

Chemical methods

- Apply Neem cake at 150 kg/ha

- Foliar spray with Neem oil at 3% (15 lit /ha) starting from disease appearance.
- Soil application of *P. fluorescens* talc based formulation at 30 DAT @ 2.5 Kg/ha and foliar spray (0.2%) at boot leaf and 10 days later @ 1 Kg/ha.
- Hexaconazole 75% WG @ 100mg/ lit 1st spray at the time of disease appearance and 2nd spray 15 days later (or)

Brown Spot: ***Helminthosporium oryzae***

Symptoms

- Brown Spot is also called as sesame leaf spot or *Helminthosporiosis,* attacks seedling in nursery to milky stage in main field.
- The disease appears first as minute brown dots later becoming cylindrical or oval to circular (resemble sesame seed).
- Spots measures 0.5 to 2.0 mm in breadth - coalesce to form large patches leads to leaf dries up.
- Seedlings die and affected nurseries can be often recognized from a distance by their brownish scorched appearance. Dark brown or black spots also appear on glumes.
- In severe cases yield reduction is up to 50%.

Fig. 5 Brown spot

Favourable Conditions

- Temperature around 25-30 ^{0}C with relative humidity above 80 per cent are highly favourable.
- Excess of nitrogen aggravates the disease incidence.

Management

Cultural methods

- As disease is seed borne, Use disease free seeds.
- Removal of alternate & collateral hosts.
- Growing resistant varieties like ADT 44, PY 4, CORH1, CO44, Cauvery, Bhavani, TPS 4 and Dhan.

Chemical method

- Seed soak / seed treatment with Captan or Thiram at 4.0g /kg of seed or treat the seed with Agrosan or Ceresan 2.5 g/kg seed to ward off appearance of seedling blight stage..
- Seed treatment with tricyclazole followed by spraying of mancozeb + tricyclazole at tillering and late booting stages gave good control of the disease.

False smut: ***Ustilagonoidea virens***

Symptoms

- Individual rice grain transformed into a mass of yellow fruiting bodies
- Growth of velvetty spores that enclose floral parts
- Infected grain has greenish smut balls with a velvetty appearance.
- The smut ball appears small at first and grows gradually up to the size of 1 cm.
- It is seen in between the hulls and encloses the floral parts.
- As the fungi growth intensifies, the smut ball bursts and becomes orange then later yellowish-green or greenish-black in color.
- Infection usually occurs during the reproductive and ripening stages, infecting a few grains in the panicle and leaving the rest healthy.

Fig. 6 False smut

Management

Cultural methods:

- Among the cultural control, destruction of straw and stubble from infected plants is recommended to reduce the disease.
- Use varieties that are found to be resistant or tolerant against the disease in India.
- Avoid field activities when the plants are wet.
- Early planted crop has less smut balls than the late planted crop.

Chemical methods

- Seed treatment with carbendazim 2.0g/kg of seeds.
- Spraying of copper oxychloride @ 2.5 g/litre or Propiconazole @ 1.0 ml/litre at boot leaf and milky stages will be more useful to prevent the fungal infection.
- At tillering and preflowering stages, spray Hexaconazole @ 1ml/lit or Chlorothalonil 2g/lit.
- At tillering and pre-flowering stages, spraying of carbendazim fungicide or copper base fungicide can effectively control the disease

* * * * * * * *

Metagenomics and Meta Transcriptomics

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Shotgun metagenomic research has been of significant importance in the characterization of the taxonomic and functional profiles of microbial communities during the past two decades. Next-generation sequencing (NGS)-based metagenomics technologies were initially employed in the clinical domain for the purpose of pathogen detection (Gu *et al*., 2019). Subsequently, these technologies have gained increasing prominence in the field of plant disease diagnostics (Piombo *et al*., 2021). Shotgun metagenomics is a technique that enables the comprehensive sequencing of the complete genomes of microorganisms found in a given sample. This sample might include many sources, such as symptomatic or asymptomatic host plants, as well as soil and other environmental matrices. This approach is considered reliable and effective for the detection and identification of pathogens. Consequently, a meticulous diagnosis has been established (Mechan *et al*., 2020). This technology offers a significant benefit by eliminating the need for prior isolation of pathogens in culture. This is particularly advantageous for obligate pathogens, which cannot be cultured. Additionally, this technology does not rely on specific probes or primers for individual pathogens, thereby avoiding the biases commonly associated with PCR and metabarcoding amplification.

The complexity of the analysis involved in sequencing data necessitates a thorough examination of potential flaws. Following the quality control of the reads and the assembly of metagenomic contigs, the data undergoes a process known as "binning" to generate entire genomes. By enabling the construction of comprehensive genomes through the use of specialized software tools like BUSCO (Simao *et al*., 2015) and CheckM (Parks *et al*., 2015), the process of binning makes it easier to identify novel pathogens. But this method has problems when used on samples with fragmented genomes. This is likely because of things like not enough coverage or the presence of very different communities with closely related species (Knight *et al*., 2018). Shotgun metagenomics, when implemented with a high sequencing depth, enables accurate taxonomic identification at the species level. This method is particularly effective for identifying the most prevalent species, especially those with whole genomes stored in databases. In recent literature, notable instances of achieving species-level resolution through the utilization of high-throughput sequencing (HTS) technologies have been documented.

For instance, Yang *et al*. (2022) employed the Oxford Nanopore Technologies MinION sequencing platform to differentiate between the boxwood blight fungal pathogens *Calonectria pseudonaviculata* and *Calonectria henricotiae*. A comparative analysis of the capabilities of two third-generation sequencing devices, namely MinION by Oxford Nanopore Technologies and Sequel by Pacific Biosciences. The objective of their investigation was to evaluate the efficacy of these instruments in the identification and diagnosis of fungal and oomycete infections found in Pinaceae and Solanum tissues. This assessment was carried out using a metagenomic method.

The integration of metagenomics and meta-transcriptomics is of significant importance in order to comprehensively understand the genetic capabilities and metabolically active species within the entire microbiome. High-throughput sequencing (HTS) plays a crucial role in the field of meta-transcriptomics since it enables the sequencing of the entire transcriptome. This comprehensive approach facilitates the identification of isoforms, unique transcripts, alternative splice variants, and subsequently, genomic variants. In their study, Garalde *et al*., (2018) employed Oxford Nanopore Technologies to perform direct sequencing of natural RNA. This approach circumvented the need for reverse transcription and amplification, enabling the acquisition of whole RNA sequences. The annotation of expressed genes is facilitated by the absence of

introns, which allows for rapid identification. However, in the context of metagenomics, the accurate taxonomic classification of fungal transcripts at the species level heavily relies on the presence of full genomes. In a recent study, Chialva *et al.,* (2019) employed an RNA-seq dataset that had been previously created for tomato plants in order to identify and analyze the taxonomic and functional diversity of the root microbiota.

References

Chialva, M., Ghignone, S., Novero, M., Hozzein, W.N., Lanfranco, L. and Bonfante, P. (2019). Tomato RNA-seq data mining reveals the taxonomic and functional diversity of root-associated microbiota. *Microorganisms*, *8*, 38.

Garalde, D.R., Snell, E.A., Jachimowicz, D., Sipos, B., Lloyd, J.H., Bruce, M., Pantic, N., Admassu, T., James, P., Warland, A., *et al.* (2018). Highly parallel direct RNA sequencing on an array of nanopores. *Nat. Methods*, *15*, 201–206.

Gu, W., Miller, S. and Chiu, C.Y. (2019). Clinical metagenomic next-generation sequencing for pathogen detection. *Annu. Rev. Pathol.*, *14*, 319–338.

Knight, R., Vrbanac, A., Taylor, B.C., Aksenov, A., Callewaert, C., Debelius, J., Gonzalez, A., Kosciolek, T., McCall, L.I., McDonald, D., *et al.* (2018). Best practices for analysing microbiomes. *Nat. Rev. Microbiol.*, *16*, 410–422.

Mechan Llontop, M.E., Sharma P., Aguilera Flores, M., Yang, S., Pollok, J., Tian, L., Huang, C., Rideout, S., Heath, L.S., Li, S., *et al.* (2020). Strain-level identification of bacterial tomato pathogens directly from metagenomic sequences. *Phytopathology*, *110*, 768–779.

Parks, D.H., Imelfort, M., Skennerton, C.T., Hugenholtz, P. and Tyson, G.W. (2015). CheckM: Assessing the quality of microbial genomes recovered from isolates, single cells, and metagenomes. *Genome Res.*, *25*, 1043–1055.

Piombo, E., Abdelfattah, A., Droby, S., Wisniewski, M., Spadaro, D. and Schena, L. (2021). Metagenomics approaches for the detection and surveillance of emerging and recurrent plant pathogens. *Microorganisms*, *9*, 188.

Simao, F.A., Waterhouse, R.M., Ioannidis, P., Kriventseva, E.V. and Zdobnov, E.M. (2015). BUSCO: Assessing genome assembly and annotation completeness with single-copy orthologs. *Bioinformatics*, *31*, 3210–3212.

Yang, S., Johnson, M.A., Hansen, M.A., Bush, E., Li, S. and Vinatzer, B.A. (2022). Metagenomic sequencing for detection and identification of the boxwood blight pathogen Calonectria pseudonaviculata. *Sci. Rep.*, *12*, 1399.

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Insect Killer's: The Entomofungal Pathogens

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Indiscriminate use of pesticides by farmers to control economically important pest for several years led to severe ecological changes such as reduction in the population of beneficial soil microbes and insect as well as development of resistance in to the insect pest. It has also affected the water quality by groundwater contamination and accumulation of toxic chemical residues on food crops have deteriorating effects on human health. Therefore, these problems have forced the industry and scientists to ponder over the situation and to focus the development of alternative control measures. One of them is biopesticide prepared from microbial inoculants such as entomofungal pathogens which can be a parasite to quick killer causes secondary infection to insect pest, substantially develops mycosis and helps in control the insect population in nature. This enomopathogens are host specific and has minimal risk of attack to non-target organism. Entomopathogens becoming popular because of their specific nature and ecologically sustainable option to regulate insect pest. Entomopathogens have different approach to cause disease as compared to other microorganisms as they do not require ingestion rather, they infect through insect cuticle. The range of insect infection includes lepidoptera, diptera, hemiptera, coleopteran, hymenoptera which is a great concern in agriculture worldwide. It is important that entomopathogen should be virulent in nature. The virulence of fungal entomopathogens involves four steps: adhesion, germination, differentiation and penetration. Fungal spore or conidia disseminated through environment cause infection in the host insect. These propagules deposited on insect cuticle a multilayer structure which is the first barrier and its composition affects the penetration process. When attached to suitable host, recognition signal (lectins) are exchanged from both host and pathogen for successful colonization. A cascade of recognition and enzyme secretion initiates the germination process on suitable host. These layers are degraded by mechanical force and various enzymes such as proteases, chitinases and lipases act in order to the substrate encounter in their path. When this pathogen crosses the external barrier it forms germ tube or appresorium and gets entry to insect where it starts invading the insect body and hemolymph. The fungus utilize nutrients from host body and cause subsequent tissue damage. Low molecular weight secondary toxic metabolites are secreted in the insect body and death of the host insect takes place. After multiplying in to the host tissues it emerges and develops infection over the insect body (Mycosis) in suitable environmental conditions. Insects become hard and paralyzed by the action of entomofungal pathogens. The whole process depends on several factors which include temperature, humidity, carbon and nitrogen source, composition of insect cuticle.

Reports have shown various entemopathogens used for control of economically important insect pest. First report of controlling insect pest with fungus given by Agostino Bassi in mid 17th century by *Beauveria bassiana* for silkworm causing a white muscardine disease. The fungus named in 1912 by the French physician Jean Paul Vuillemin in the honor of French scientist Jean Beauverie. Fungus produces dry, powdery conidia in distinctive white spore balls. The conidiogenous cells of *B. bassiana* are short and ovoid, and terminate in a narrow apical extension called a rachis. Latter Elie Metchnikoff in mid-18th century demonstrated that green muscardine disease was caused by *Entomopthora anisopliae* against wheat cockchafers (*Anisoplia austriaca*). Later this fungus recognized as *Metarhizium* Greek word meta means change combined with another Greek word rhiza means root and the mycelium termed as root part of

the fungus by Sorokin. Conidia are long cylindrical spore like budding like body usually in group or sometimes in dispersed manner. *Lecanicillium lecanii* are opportunistic fungus widely called as the "white holo" and it causes mycosis in a number of insects of orders Homoptera, Coleoptera and Lepidoptera. *Paecilomyces* described as diverse fruiting structure. The Greek word poikilos means diverse and Latin word mykes means myces however this genera has been transferred in to *Isaria*. *Nomuraea* named after the scientist H. Nomura from Japan. The fungus infected Pionea *forficalis*. Other entomopathogens used widely to control insect pest are listed in table 1.

The use of entomopathogens to control insect pest is agriculturally sustainable option for farmers and it will also help to produce the healthy food by eliminating application of dangerous pesticides. It will also help to maintain soil health and environmental balance. However, many researchers have been criticised entomopathogens as biocontrol agents because its action is too slow, another drawback reported is lack of persistence and widespread activity. Apart from that these entomopathogens fails to stand at high temperature and in dry area. Lack of proper delivery system is also an area of research.

Entmopathogens	**Effective against insect pest**	**Metabolite**
Beauveria bassiana, B. brogniartii	*Sitophilus oryzae, S. zeamais, Schistocerca gregaria, Ostrinia nubilalis, Helicoverpa Armigera,* Whiteflies/Aphids/Thrips	Bassiacridin, Bassianin, Bassianolide
Metarhizium anisopliae, M. flavo-viride	Grasshoppers, Thrips, Cockchafers, Spittlebugs, Grubs, Borers and Ticks	Destruxins, Cytochalasin
Nomuraea rileyi, N. atypicola	Spiders , *Anticarsia gemmatalis, Spodoptera litura, Helicoverpa armigera, Thysonoplusia orichalcea*	
Lecanicillium lecanii	Aphids, Whiteflies, Scales, Mealybugs, Thrips, Epilachna beetles	Dipcolonic acid, hydroxycarboxylic, acid, Vertilecanins, aphidicolin
Isaria fumosorosea	Whiteflies/Thrips, Mites	Leucinostatins , beauverolides, isariotins A–F
Hirsutella gigantean, H. thompsonii, H. cryptosclerotium	*Rastrococcus invadens*	Hirsutellin A, Hirsutellin B, Phomalatone, hirsutellic acid
Aschersonia aleyrodis	Coccidae and Aleyrodidae,	Ascherxanthone A
Conidiobolus coronatus	*Reticulitermes xavipes,* Aphids	
Coelomomyces sp.	Mosquitoes and Chironomids	
Entomophthora muscae	Houseflies	
Tolypocladium sp.	*Rhopalosiphum padi*	Cyclosporin, Efrapeptins

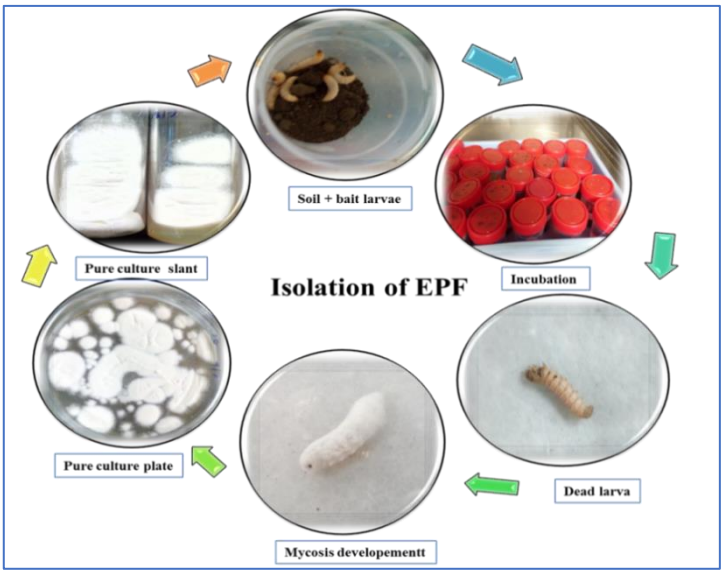

Fig. 1. Isolation and purification of entomopathogen

Isolation process

Isolation of entomopathogenic fungi can be done by insect bait method in which approximately 50 g of soil added into sterile container and then 5-10 larvae of *Galleria melonella* (Wax moth) or *Corcyra cephalonica* (Rice moth) are added in separate container. It is necessary to maintain moisture level according to prescribed standards, these containers

then incubated in growth chamber where temperature is maintained at 25°C and humidity as 70%. Ten days after incubation deformed and mummified larvae can be observed and separated.

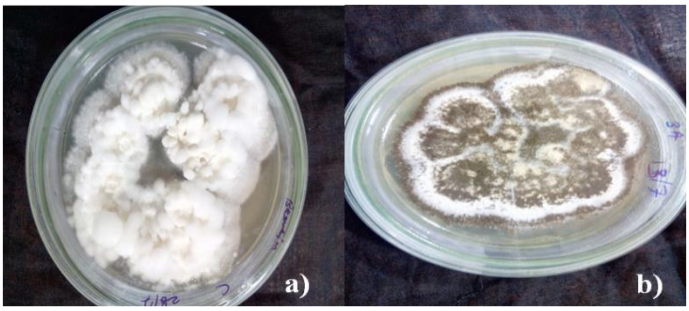

Fig 2. Colony morphology of *Beauveria* sp. and *Metarhizium* sp.

These dead larvae further kept on sterile moist filter paper in sterile Petri plate and sealed with parafilm and incubated for further mycosis development. When mycosis is developed after 2-3 days, insect cadavers need to be surface sterilized with 2% sodium hypochlorite and washed with distilled water twice. Small bits of this cadaver then streaked on Sabouraud dextrose agar plates fortified with 0.5 % yeast extract. Fig. 1 illustrates the isolation process and fig. 2 depicts colony morphology of the two different fungi after isolation.

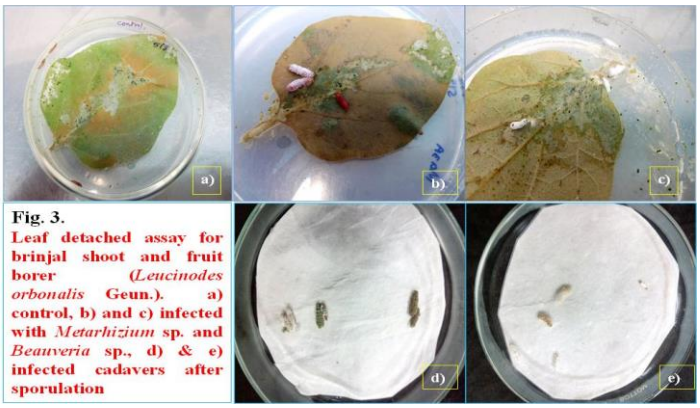

Fig. 3.
Leaf detached assay for brinjal shoot and fruit borer (*Leucinodes orbonalis* Geun.). a) control, b) and c) infected with *Metarhizium* sp. and *Beauveria* sp., d) & e) infected cadavers after sporulation

Bioassay

Leaf detached bioassay (Fig. 3)

In this bioassay clean, tender and fresh leaves of brinjal are rinsed with distilled water and then dipped in Sodium hypochlorite (1%) solution for two minutes, followed by two rinses in distilled water. After complete drying in aseptic condition, they are dipped in spore suspension for 30 seconds further dried in laminar air flow. After that they are placed individually in Petri plates containing sterilized agar medium (1%). Care should be taken that petiole of the leave is inserted deep into agar plate it will help to avoid water loss of the leave. To avoid bacterial contamination Chloramphenicol is added to the medium. Target insects are dipped in spore suspension for 2 seconds and excess solution is drained off and transferred to leaves placed over the agar medium. The petri plates are sealed with parafilm to avoid escape of aphids as well as to enhance the settlement of aphids on the leaf. The plates are maintained in an incubator at 25 ± 0.5°C. The newly hatched should be removed from the plates aseptically in laminar air flow before counting to avoid confusion in calculations.

References

Charnley AK and Collins SA. Entomopathogenic Fungi and Their Role in Pest Control Environmental and Microbial Relationships pp 159-187 Part of the The Mycota book series (MYCOTA, volume 4)

Feng MG and Johnson JB. (1990). Relative susceptibility of six isolates of *Beauveria bassiana* on *Diuraphis noxia* (Homoptera: Aphididae). Environ. Entomol, 19:785-790.

Ferron P (1978). Biological control of insect pests by entomogenous fungi. Ann. Rev. Entomol. 23:409-42.

Molnar I, Gibson DM and Krasnoff SB (2010). Secondary metabolites from entomopathogenic Hypocrealean fungi. Nat. Prod. Rep. 27:1241–1275.

Ramanujam B, Rangeshwaran R, Sivakmar G, Mohan M and Yandigeri MS (2014). Management of Insect Pests by Microorganisms. *Proc Indian Natn Sci Acad* 80: 455-471.

Shahid AA, Rao AQ, Bakhsh A and Husnain T (2012). Entomopathogenic fungi as biological controllers:New insights into their virulence and pathogenicity. Arch Biol Sci. 64 (1): 21-42.

Scorsetti AC, Elíades LA, Stenglein SA, Cabello MN, Pelizza SA and Saparrat MC. (2012). Pathogenic and enzyme activities of the

entomopathogenic fungus *Tolypocladium cylindrosporum* (Ascomycota: Hypocreales) from Tierra del Fuego, Argentina. Rev Biol Trop 60(2):833-41.

Ujjan AA and Shahzad S. (2012). Use of entomopathogenic fungi for the control of mustard aphid (*Lipaphis erysimi*) on canola (*Brassica napus L.*) *Pak.J. Bot.*, 44(6): 2081-2086.

Vega FE, Goettel MS, Blackwell M, Chandler D, Jacksone M, Keller S, Koike M, Maniania NK, Monzon A, Ownley BH, Pell JK, Rangel DEN, Roy HE. (2009). Fungal entomopathogens: new insights on their ecology. Fungal Ecology 2 (2009) 149–159.

Zimmermann G (1986). The ''Galleria bait method'' for detection of entomopathogenic fungi in soil. Z Angew Entomol. 102:213–215.

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Metabarcoding Applications in Microbiota

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Metabarcoding refers to a molecular technique used to identify and quantify many species within a given environmental sample. Metabarcoding has demonstrated its efficacy as a cost-efficient approach for characterizing microbial communities. This method enables the assessment of biodiversity within samples, offering a high level of taxonomic precision. Additionally, it facilitates the comparison of sample communities that have been treated with various treatments. From a bioinformatic perspective, shotgun metagenomics is somewhat more challenging to handle because of its higher storage requirements and processing demands. Currently, this method is widely employed as the predominant molecular technique for characterizing microbiota in environmental samples (Francioli *et al*., 2021). This work provides novel insights into the examination of plant illnesses characterized by intricate causes occurring in both the aboveground and belowground components of plants.The efficacy of DNA metabarcoding is mostly contingent upon the careful selection of a suitable DNA marker gene. The selection of primers should possess suitable coverage of the target group, effective exclusion of outgroups, and the capability to differentiate taxa based on the nucleotide variability of the amplified marker (Tedersoo *et al*., 2022). The utilization of customer-designed primer pairs, as exemplified in the genome-enhanced detection and identification (GEDI) approach outlined below, is a viable option. However, it is equally crucial to incorporate universal primers on barcodes to facilitate cross-study comparisons. In order to analyze fungal communities, researchers commonly employ DNA barcoding and metabarcoding techniques. Among the various markers available, the internal transcribed sequence (ITS) region of the ribosomal RNA (rRNA) is widely utilized due to its numerous copies and ability to provide accurate species-level identification in most fungal groups (Tedersoo *et al*., 2022). However, it is important to note that certain groups, such as Trichoderma, *Fusarium*, or Oomycetes, may not exhibit complete resolution at the species level using the ITS region.

The fundamental aspects of analyzing metabarcoding sequencing data encompass (i) the process of grouping sequences and (ii) the attribution of taxonomic or functional information through comparison with existing databases. Sequence readings are grouped together based on their similarity. In most metabarcoding studies, operational taxonomic units (OTUs) are made by grouping readings that are similar to each other by a certain amount, usually between 95% and 99%. Typically, a threshold of 97% homology is employed. In order to enhance the accuracy and consistency of taxonomic identification, researchers have devised amplicon sequence variant (ASV) methodologies. For future assessments of the community, these methods only look at unique, identical sequences. They focus on OTUs (operational taxonomic units) that are 100% alike. After the clustering process, the reads need to be allocated to a taxon or a function, depending on the reference databases, in order to make taxonomic or functional assignments. The quality of the information obtained improves as the databases become more carefully selected and comprehensive. The identification of ITS sequences from fungal and other eukaryotic organisms is commonly conducted using the UNITE reference data set, which is accessed through the website https://unite.ut.ee (accessed on March 16, 2022). This database is widely utilized due to its extensive curation and inclusion of diverse non-

fungal sequences, which aid in the differentiation of fungi from other eukaryotes (Anslan *et al*., 2018; Nilsson *et al*., 2019). Functional assignments can be made using either the FUNGuild database (Nguyen et al., 2016) or the FungalTraits database (Polme *et al*., 2020). It is noteworthy to emphasize that next-generation sequencing (NGS) microbiome-based diagnostics provide a substantial volume of data, necessitating the utilization of machine learning or other resources for the evaluation of human, plant, and soil health (Oh *et al*., 2020; Krause *et al*., 2021; Wilhelm *et al*., 2022). The efficacy of bioinformatic methodologies in the retrieval of fungal strains and the corresponding proportions of the retrieved strains exhibited significant heterogeneity. The sequence analysis tools, namely USEARCH and VSEARCH, were successful in detecting nearly all strains present in the mock community. However, both methods tended to exaggerate the richness of the community. On the other hand, the DADA2 tool demonstrated more accuracy in retrieving both the true richness and composition of the mock community. The first two methods are better suited for identifying specific species, whereas the third method is better suited for doing studies on community ecology (Pauvert *et al*., 2019).

Fusarium Head Blight (FHB) is a major wheat disease caused by many *Fusarium* species, many of which can make mycotoxins (Karlsson *et al*., 2021). FHB can affect both above-ground and below-ground tissues. The wheat ear fungus community in a topographically varied environment was characterized using Illumina MiSeq with V3 Chemistry (Schiro *et al*., 2019). In other study, employed PacBio CCS long read sequencing to investigate the alterations occurring in *Fusarium* spp. by targeting a combination of the highly variable internal transcribed spacer (ITS) and the D1-D2-D3 portions of the large subunit (LSU) region. The investigation examines the impact of various cover crops on crop leftovers. In a similar manner, the amplification of bacterial 16S rRNA, fungal ITS, and *Fusarium* spp. is performed using the Illumina MiSeq platform in maize. The utilization of TEF1 areas provides valuable insights into the intricate epidemiology of *Fusarium* head blight (FHB) through the identification and concurrent appearance of various phytopathogenic and beneficial bacteria in maize stalks cultivated in conjunction with wheat. The investigation involved the analysis of fungal and bacterial community profiles in wheat straws that were intentionally inoculated with *Zymoseptoria tritici*. This allowed for comprehensive knowledge of the interactions and dynamics between the pathogen and the entire microbial community for a specified period of time (Kerdraon *et al*., 2019). The utilization of next-generation sequencing (NGS) techniques in grapevine cultivation presents numerous advantageous applications in determining the microbial species composition that is pertinent to the process of winemaking (Singh *et al*., 2019; Griggs *et al*., 2021).

The utilization of next-generation sequencing (NGS) techniques has been employed to characterize clusters of grapevine trunk diseases, specifically *Eutypa, Esca, Botryosphaeria*, *Phomopsis* dieback, and black foot. The accurate characterization of these diseases is essential in order to determine and implement the most suitable control strategies. The utilization of Illumina short read technology, together with optimized and universal primers designed to target both the ITS1 and ITS2 rDNA regions, has been employed to validate the existence of the most prominent species associated with each condition. Furthermore, this approach has facilitated the identification of species that have not yet been classified within this particular complex (Morales *et*

al., 2018). In contrast to the relatively high level of attention given to wood diseases, the detection of Vitis phylloplane diseases using next-generation sequencing (NGS) has garnered comparatively less interest. However, it is anticipated that the utilization of NGS for this purpose will increase in the near future (Cureau *et al*., 2021). Next-generation sequencing (NGS) was employed to investigate the impact of elicitors or biocontrol agents on the populations of microorganisms residing on the surface of leaves (Gobbi *et al*., 2020; Nerva *et al*., 2019). Apple Replant Disease (ARD) is a significant ailment characterized by a multifaceted origin that mostly impacts fruit trees, specifically apples and other members of the Rosaceae family that are replanted in a location previously used for agriculture (Mazzola *et al*., 1998). The primary species involved in many apple locales globally are oomycetes, including *Pythium* spp. and *Phytophthora* spp., as well as fungi, particularly *Cylindrocarpon* spp. and *Rhizoctonia solani*.

The management of acid rock drainage (ARD) poses challenges attributed to the limited availability of approved chemical treatments, which are further compounded by the intricate nature of the disease's causative factors. The application of next-generation sequencing (NGS) methods has revealed substantial disparities in microbial composition between newly established sites and replanted sites, particularly in populations of beneficial bacteria such as *Burkholderia* spp., Microcoleus, Nocardioides, sulfur-oxidizing bacteria, and those involved in nitrogen cycling. Additionally, these differences have been observed following the use of green manure with Brassica spp. The user's text does not contain any information. Next-Generation Sequencing (NGS) has been employed in other studies to investigate and describe the pathobiome of many crops, including oaks, ginseng, tomato, strawberry, potato, banana and ramie (*Boehmeria nivea*). The metabarcoding technique is commonly employed for the investigation of oomycetes, with a particular focus on *Phytophthora* spp. The second box The utilization of high-throughput sequencing (HTS) has significantly enhanced our capacity to evaluate biodiversity in fungal communities across various ecosystems, including soil, phylloplane, air, and water. This technological advancement has particularly facilitated the monitoring of a specific pathogen's dynamics within its dynamic environment. For instance, it enables the examination of the pathogen's behavior following chemical or biological interventions, as well as the investigation of the impact of climate change or agricultural practices on disease development. Understanding the structure and function of microbiota linked to various settings, such as roots, leaves, suppressive soils, and degraded soils, requires comprehensive knowledge of soil microbial communities and their compositions and diversity.

Several fungi have the ability to adopt several lifestyles, including harmful, saprophytic, or symbiotic. The boundaries of idioms are frequently ambiguous, resulting in a lack of clarity. Individuals have the ability to modify their way of existence, for instance, through the process of endophytes transitioning into parasites and vice versa. This can be achieved through the utilization of omics, which refers to a set of instruments and novel methodologies employed to investigate plant-microbe interactions and gain a better understanding of the various behaviors involved (Bahram *et al*., 2022). Microbiome studies have gained significant traction in the field of environmental research. These studies have been employed to assess biodiversity levels and facilitate conservation efforts in protected regions. Additionally, they have been utilized to investigate the influence of various factors such as host taxon,

tissues, and seasonality on the composition of fungi and bacteria in tropical forests (Li *et al*., 2022). Furthermore, microbiome studies have been instrumental in comparing the microbiomes of trees and associated herbaceous plants used for phytoremediation purposes (Yung *et al*., 2021).

Reference

Anslan, S., Nilsson, R.H., Wurzbacher, C., Baldrian, P., Tedersoo, L. and Bahram, M. (2018). Great differences in performance and outcome of high-throughput sequencing data analysis platforms for fungal metabarcoding. *MycoKeys*, *39*, 29–40.

Bahram, M. and Netherway, T. (2022). Fungi as mediators linking organisms and ecosystems. *FEMS Microbiol. Rev.*, *46*, fuab058.

Cureau, N., Threlfall, R., Savin, M., Marasini, D., Lavefve, L. and Carbonero, F. (2021). Year, location, and variety impact on grape-, soil-, and leaf-associated fungal microbiota of arkansas-grown table grapes. *Microb. Ecol.*, *82*, 73–86.

Francioli, D., Lentendu, G., Lewin, S. and Kolb, S. (2021). DNA Metabarcoding for the Characterization of Terrestrial Microbiota-Pitfalls and Solutions. *Microorganisms*, *9*, 361.

Gobbi, A., Kyrkou, I., Filippi, E., Ellegaard-Jensen, L. and Hansen, L.H. (2020). Seasonal epiphytic microbial dynamics on grapevine leaves under biocontrol and copper fungicide treatments. *Sci. Rep.*, *10*, 681.

Griggs, R.G., Steenwerth, K.L., Mills, D.A., Cantu, D. and Bokulich, N.A. (2021). Sources and assembly of microbial communities in vineyards as a functional component of winegrowing. *Front. Microbiol.*, *12*, 673810.

Krause, T., Wassan, J.T., McKevitt, P., Wang, H., Zheng, H. and Hemmje, M. (2021). Analyzing large microbiome datasets using machine learning and big data. *BioMedInformatics*, *1*, 138–165.

Mazzola, M. (1998). Elucidation of the microbial complex having a causal role in the development of apple replant disease in Washington. *Phytopathology*, *88*, 930–938.

Morales-Cruz, A., Figueroa-Balderas, R., García, J.F., Tran, E., Rolshausen, P.E., Baumgartner, K. and Cantu, D. (2018). Profiling grapevine trunk pathogens in planta: A case for community-targeted DNA metabarcoding. *BMC Microbiol.*, *18*, 214.

Nerva, L., Pagliarani, C., Pugliese, M., Monchiero, M., Gonthier, S., Gullino, M.L., Gambino, G., Chitarra, W. (2019). Grapevine phyllosphere community analysis in response to elicitor application against powdery mildew. *Microorganisms*, *7*, 662.

Nguyen, N.H., Song, Z., Bates, S.T., Branco, S., Tedersoo, L., Menke, J., Schilling, J.S. and Kennedy, P.G. (2016). FUNGuild: An open annotation tool for parsing fungal community datasets by ecological guild. *Fungal Ecol.*, *20*, 241–248.

Nilsson, R.H., Larsson, K.H., Taylor, A.F., Bengtsson-Palme, J., Jeppesen, T.S., Schigel, D., Kennedy, P., Picard, K., Glöckner, F.O., Tedersoo, L., *et al.* (2019). The UNITE database for molecular identification of fungi: Handling dark taxa and parallel taxonomic classifications. *Nucleic Acids Res.*, *47*, D259–D264.

Oh, M. and Zhang, L. (2020). DeepMicro: Deep representation learning for disease prediction based on microbiome data. *Sci. Rep.*,*10*, 6026.

Pauvert, C., Buee, M., Laval, V., Edel-Hermann, V., Fauchery, L., Gautier, A., Lesura, I., Vallance, J. and Vacher, C. (2019). Bioinformatics matters:

The accuracy of plant and soil fungal community data is highly dependent on the metabarcoding pipeline. *Fungal Ecol.*, *41*, 23–33.

Polme, S., Abarenkov, K., Nilsson, R.H., Lindahl, B.D., Clemmensen, K.E., Kauserud, H., Nguyen, N., Kjøller, R., Bates, S.T., Baldrian, P., *et al.* (2020). FungalTraits: A user-friendly traits database of fungi and fungus-like stramenopiles. *Fungal Divers.*, *105*, 1–16.

Schiro, G., Colangeli, P. and Müller, M.E.H. (2019). A metabarcoding analysis of the mycobiome of wheat ears across a topographically heterogeneous field. *Front. Microbiol.*, *10*, 2095.

Singh, P., Santoni, S., Weber, A., This, P. and Péros, J.P. (2019). Understanding the phyllosphere microbiome assemblage in grape species (Vitaceae) with amplicon sequence data structures. *Sci. Rep.*, *9*, 14294.

Tedersoo, L., Bahram, M., Zinger, L., Nilsson, R.H., Kennedy, P.G., Yang, T., Anslan, S. and Mikryukov, V. (2022). Best practices in metabarcoding of fungi: From experimental design to results. *Mol. Ecol.*, *31*, 2769–2795.

Wilhelm, R.C., van Es, H.M. and Buckley, D.H. (2022). Predicting measures of soil health using the microbiome and supervised machine learning. *Soil Biol. Biochem.*, *164*, 108472.

Yung, L., Bertheau, C., Tafforeau, F., Zappelini, C., Valot, B., Maillard, F., Selosse, M.A., Viotti, C., Binet, P., Chiapusio, G., *et al.* (2021). Partial overlap of fungal communities associated with nettle and poplar roots when co-occurring at a trace metal contaminated site. *Sci. Total Environ.*, *782*, 146692.

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Plasma Technology – A Solution to Fungal Contaminants of Maize

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Maize (*Zea mays* L.) is the world's third most significant cereal crop, trailing only wheat and rice (Aldrich et al., 1975). It has significant potential as a cereal crop due to its low production costs, wide flexibility, and numerous uses. A variety of causes contribute to yield loss, with sickness playing a significant role. At the seedling stage, maize is infected with 28 diseases, 11 of which are seed-borne (Fakir, 2001). Several scientists have reported that seed-borne pathogens have a significant impact on seed production and the food industry because they can affect seed germination and plant growth, cause seed and seedling diseases and mycotoxin contamination of grains (Singh *et al*., 2011; Magan and Olsen, 2004; Barros *et al*., 2011). Damages induced by seed-borne infections, such as seed death, seedling and plant deformities, or diminished seed vigour, are not often noticed by users (Mukhtar, 2009).

Rapid seed invigoration and seedling establishment are required throughout the early growth phases of crops to prevent agricultural yield loss owing to unfavourable environmental conditions. Seed germination and early seedling growth are the most vulnerable stages of crop development to a variety of environmental stresses (Jisha *et al*., 2013 and Sharma *et al*., 2015). When stressors influence seeds or plants during the early phases of growth, they can delay the onset, diminish the rate, and reduce the uniformity of germination and seedling emergence. Plant growth and agricultural yield are lowered as a result. As a result, seed invigoration is employed to promote germination and seedling vigour (seedling size, health, and pace of growth). Many efforts have been made to improve seed germination and seedling vigour under both adverse and non-adverse conditions, including the use of chemical treatments such as sulfuric acid, pesticides, and chlorine-based disinfectants (Ashraf and Foolad, 2005; Kimura and Islam, 2012; Jisha et al., 2013; Sharma et al., 2015). Synthetic chemical treatments involve soaking seeds or spraying young plants with chemical-containing solutions. However, the use of synthetic chemical treatments can lead to a rise in chemical pollutants in seeds or young plants, which can have a negative impact on human health and the environment.

Furthermore, pathogenic fungi damage food grains during storage by creating mycotoxins and aflatoxins, threatening their nutritional integrity (Park et al., 2004; Koirala *et al*., 2005; Domijan *et al*., 2005). Aspergillus and Fusarium species were the most common fungus infecting seed germplasm (Askun, 2006; Fandohan et al., 2003). Previously, Anne et al., (2000), Curtui *et al*., (1998), and Susan *et al*., (2005) isolated several Fusarium species from maize seed. Fusarium and Aspergillus species were prevalent maize fungal pollutants that produced high levels of mycotoxins (Bakan *et al*., 2002; Verga *et al*., 2005).

Plasma technology

Plasma technology, a new approach, has been extensively designated as an enhanced oxidation process (Misra et al., 2011; Ekezie et al., 2017; Fan and Song, 2020). Although large-scale uses of plasma technology are still pricey, it has advantages over conventional treatments based on synthetic chemical compounds. The synergistic effects of plasma technology on seed germination and seedling vigour without synthetic chemical residues are a considerable advantage. Plasma treatment has recently gained popularity as a pre-sowing seed treatment method to increase seed quality and decontaminate microorganisms on the seed coat surface. Plasma is a partially ionised plasma that contains positive and negative ions, electrons, neutrals, molecules, photons, and ultraviolet light.

Plasma, commonly known as the "fourth state of matter," is made up of ionised gas, atoms, free molecules, radicals, and free electrons. Since its discovery in the late nineteenth century, plasma has

been widely used in a variety of industrial applications such as microelectronic technology, the textile industry, organic waste management, and so on. When a gas is pushed through an electric field in a plasma chamber, three types of collisions are known to occur: excitation, ionisation, and deposition, which furnish plasma with its characteristic glow, ion-electron pair, and reactive species. The chemical and physical properties of several objects can be altered via plasma treatment.

Application of plasma in Seed Science

Many seed quality enhancement strategies are utilised in seed science and research to increase seed quality in agricultural plants, such as seed priming, fortification, solid matrix priming, chemical treatment, hardening, and so on. Plasma treatment of seeds is a novel technique that uses an ionised gas to affect the physical and chemical features of the seed, such as wettability, porosity, water absorption, and antioxidant enzyme activity. It can also cleanse microbial seed surfaces and convert hydrophobic seeds to hydrophilic ones. It also increases soluble sugar and protein levels while decreasing lipid peroxidation. As a result, plasma therapy enhances seed germination rate, seedling traits, seed physical quality, and seed health. Agricultural applications of non-thermal plasma for improving seed quality and crop yields, as well as decontaminating seeds, have received a lot of attention recently, owing to the fact that food shortage is becoming one of the most serious global problems in this century due to the constantly growing population and decreasing arable land (Koga et al., 2015). Numerous studies have shown that non-thermal plasma is a faster, more uniform, cost-effective, and eco-friendly method for stimulating seed germination and seedling growth than conventional seed pretreatment methods such as ultraviolet and gamma radiation, scarification, hot water soaking, and chemical reagent treatment (Li et al., 2014; Randeniya and De Groot, 2015; Mildaziene et al., 2018; Stepanova et al., 2018). Several authors have investigated the use of plasma generators to stimulate seed germination and plant growth (Zivkovic et al., 2004; Sera et al., 2010; Dobrin et al., 2015; Bafoil et al., 2018). Plasma treatment has been shown in some studies to increase seed activity, including earlier germination, higher germination rate, faster growth, and other growth parameters (Sera et al., 2010; Jiang et al., 2014), enzyme activity (Henselova et al., 2012; Surowsky et al., 2013), and plant yield (Yin et al., 2005). However, the detailed processes underpinning plasma's stimulatory effects on seeds remain unknown.

There are several methods for producing plasma, including glow discharge and dielectric barrier discharge from various gases such as air and $O_2^{\bullet-}$. When seed is exposed to plasma, the plasma interacts with the seed surface, changing its topography as well as its biochemical and physical properties. These modifications, in general, impact seed behaviour during the early stages of germination, resulting in significant variations in seed and crop performance later on. Plasma can be generated in a variety of ways, however for seed treatment, the glow discharge method is often utilised due to its qualities such as seed quality improvement, seed enhancement, and pathogen cleaning on the seed coat surface. Plasma is created in the glow discharge method by passing an electric current through a low-pressure gas. A voltage is applied between two electrodes in a glass tube containing gas to produce it. When the voltage in the tube surpasses a particular threshold, the gas ionises and changes into plasma. The ionised gas begins to conduct electricity, which causes it to glow (Mehta, 2002). It primarily increases the physiological and health components of seed quality as a post-harvest element in seed quality. Plasma treatment has been used successfully in agriculture to improve seed quality, boost seed, and inactivate harmful microorganisms (Filatova et al., 2013). Although plasma treatment has yielded promising results in a variety of crops, commercial implementation of this technology has yet to be standardized.

Among the various constituents in plasma, reactive oxygen species (ROS) [e.g., hydroxyl radical (OH), superoxide anion ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2), and singlet oxygen ($^1O_2$)] and reactive nitrogen species (RNS) [e.g., nitric oxide (NO),

nitrite ($NO2^{-}$), nitrite ($NO3^{-}$) and peroxynitrite ($OONO^{-}$)] are considered as the major agents for plasma induced biological effects (Iseni et al., 2016). ROS and RNS in plants can be beneficial or harmful depending on the amount (Panngom et al., 2018), activating a variety of physiological and metabolic behaviours (such as breaking dormancy, accelerating germination, and enhancing antioxidant capacity) at low doses while causing oxidative stress in seeds at high doses (Romero-Puertas et al., 2019). To resist oxidative stress, plants have an intrinsic antioxidant defence system that includes enzymatic antioxidants such as superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD), as well as non-enzymatic antioxidants such as ascorbate, glutathione, and proline (Liu *et al*., 2018). These antioxidants are required for the stimulation of physiological and developmental processes as well as the resistance to stress (Liu *et al*., 2007). Plasma-generated reactive species, on the other hand, could directly etch the seed husk, enhancing the seed coat permeability for oxygen, water, and other nutrition species and, as a result, boosting seed growth properties (Zhang and Kirkham, 1994). In addition to ROS and RNS, intracellular Ca^{2+} has been identified as a key signaling component in several physiological processes in plants, including hormone production, seed germination, cell division, cell expansion, pollen tube growth, and fertilization (Demidchik *et al*., 2018).

Plasma pre-treatment of seeds promotes germination while suppressing fungal and bacterial plant diseases. Crop yields are increased by immersing seeds in a low temperature plasma discharge produced by separated electrodes coupled to a high frequency electrical power supply. Scarifying seeds (a technique to soften the seed coat while keeping the seed viable), inactivating seed-borne pathogens, and enhancing antioxidant defence systems in crop plants have all been used independently (Jisha *et al*., 2013; Arajo *et al*., 2016; Antoniou *et al*., 2016; Thomas and Puthur, 2017). During the plasma treatment, the seeds may be damaged by oxygen radicals and battered by ions, resulting in the erosion of oxygen-containing functional groups in the seeds. Changes in the surfaces of plasma-treated seeds may increase the seed's hydrophilic wettability, resulting in faster water uptake. This promotes rapid seed germination. Increased seed permeability is connected with increased nutrient absorption, which may promote seedling growth.

Future research should focus on optimizing plasma seed treatment to improve water absorption and seed vigour, as well as investigating the storability and antioxidant mechanisms of plasma seed treatment on the inactivation of seed-borne pathogens in maize seeds.

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Bioactive Compounds in Jamun (*Syzygium Cumini* L.) Ensuring Plant Tolerance Towards Diseases

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Jambolan fruit exhibits a high concentration of bioactive phenolic compounds, which have the potential to exert beneficial effects on human health. The jambolan plant is known to possess many phenolic compounds, including phenolic acids, flavonoids (primarily anthocyanins, flavonols, flavanols, and flavanonols), and tannins, which are present in its diverse anatomical components. This resource is mostly employed for the cultivation of timber and the establishment of fruit orchards. The fruit has been attributed with a range of properties including anti-diabetic, anti-hyperlipidemic, anti-oxidant, anti-ulcer, hepatoprotective, anti-allergic, anti-arthritic, anti-microbial, anti-inflammatory, anti-fertility, anti-pyretic, anti-plaque, radioprotective, neuropsychopharmacological, nephroprotective, and anti-diarrheal effects. The jambolan fruit skin contains a high concentration of anthocyanins, specifically delphinidin, petunidin, and malvidin in glycosylated forms. On the other hand, the majority of the fruit pulp is composed of phenolic acids, including gallic acid and ellagic acid, as well as tannins. Moreover, it has been asserted that the jambolan fruit contains a plethora of other chemicals. Flavonoids such as quercetin, myricetin, and flavonol glycosides have been identified in the leaves of the jambolan tree, as well as in the skin and pulp of its fruit. Jambolan possesses phenolic compounds that have been associated with a wide range of health advantages, including inflammation, allergies, blood sugar regulation, cancer prevention, cardiovascular well-being, radiation treatment support, bacterial infections, chemotherapy efficacy, and more benefits. This chapter provides a comprehensive analysis of the pharmacological, nutritional, and physiological advantages associated with jamun, along with an examination of the diverse bioactive components present in this fruit. Jamun seeds contain both the alkaloid jambosine and the glycoside jambolin, which is also referred to as antimellin.

The fruit commonly known as jamun (Syzygium cumini) has garnered attention in recent years due to its high content of antioxidants and potential contributions to nutritional security. Jamun is rich in bioactive chemicals that have been associated with various health benefits.

Phytochemicals

Phytochemicals are a class of food additives that have demonstrated the capacity to confer health advantages, such as a less susceptibility to chronic ailments, but lacking inherent nutritional value. Phenolic compounds, a chemical family found in plants, have garnered the attention of researchers due to their possible antioxidant properties (Ignat et al., 2011; Singh et al., 2016). Certain types of these molecules, such as tannins, possess unfavorable characteristics, leading to the initial perception of these chemicals and other secondary metabolites in plants as antinutrients (Treutter, 2010). The prevailing notion has been conclusively debunked by the abundance of epidemiological studies that have established the significance of phenolic chemicals in conferring health advantages to individuals. The recent change in mindset has captured the attention of scientists in the field of food technology and allied disciplines, who are now focused on the characterization and quantification of phenolic chemicals present in various food sources. Jambolan *(Syzygium cumini* Skeels) is a prominent evergreen tree that is widely distributed in tropical and subtropical regions. It is alternatively referred to as jamun, jambul, black plum, or Indian blackberry.

Throughout decades, this substance has been employed in many alternative medicinal practices for its stomachic, diuretic, anti-diabetic, and diarrheic properties. Although there is a general agreement on

the possible medicinal benefits of this herb, there is a notable absence of robust scientific data to support these claims jambolan possesses several pharmacological properties, including antioxidant, antibacterial, chemopreventive, anti-inflammatory, anti-allergic, anti-hyperglycemic, anti-cancer, cardioprotective, radioprotective, and radioprotective activities.

Phenolic compounds

Phenolic compounds,which are bioactive secondary phytochemicals, are predominantly synthesized in higher plants by either the shikimic acid or phenylpropanoid pathways. Phytochemicals are predominantly found in the external layers of plant tissues and in seeds, where they exhibit defensive properties. Phenolic acids encompass a group of chemical compounds, including caffeic acid and coumaric acid generated from hydroxycinnamic acid, as well as gallic acid and ellagic acid obtained from hydroxybenzoic acid. Flavonoids are a class of phenolic compounds characterized by a structural arrangement of C6-C3-C6, wherein two aromatic rings are interconnected by a heterocyclic ring composed of three carbon atoms. Several examples of these substances are flavonols, flavanols, flavones, flavanones, isoflavones, and anthocyanins. Tannins possess a taste characterized by bitterness and astringency, and have molecular weights typically ranging from 500 to 3000, rendering them phenolic compounds that are soluble in water. Phenolic compounds find application in the food business for their preservation properties, ability to enhance flavors, and serve as colorants, with a particular emphasis on anthocyanins, which belong to the flavonoid family. Various methods exist for the detection of total phenolic content, with the Folin-Ciocalteu reagent being the most used. This method entails the reduction of phosphomolybdic or phosphotungstic acid in an alkaline solution, resulting in the formation of a complex that exhibits a distinct blue coloration. Furthermore, the utilization of mass spectrometry enables the confirmation of the existence of phenolic chemicals. In the context of high-performance liquid chromatography (HPLC) analysis, it is common practice to only utilize reversed phase C18 columns. Binary solvent systems commonly employ polar solvents in the majority of instances. It is necessary to obtain fresh samples in order to extract phenolic compounds from fruits such as jambolan. Nevertheless, due to the inherent perishability of these fruits, freeze drying or other preservation processes are commonly necessary. The quantity of phenolic chemicals present in an extract may exhibit significant variability, contingent upon the specific methodology employed during its preparation. Numerous techniques outlined in the existing body of research are characterized by a significant investment of time and complexity in terms of reproducibility (Aqil et al., 2014). On the other hand, hydrolyzable tannins and flavonols were shown to be more susceptible to oxidation and longer heating durations. The researchers discovered that the advantageous constituents, such as anthocyanins, present in jambolan juice had a notable degradation when subjected to processing temperatures exceeding 70 °C.

Flavonoids

Faria et al. (2011) discovered that jambolan fruit extracts, including both the pulp and peel, exhibited a diverse range of flavonols and flavanonols. The compounds identified in the study encompassed myricetin, myricetin pentoside, myricetin rhamnoside, myricetin glucoside, and myricetin acetylrhamnoside. Tavares et al. (2016) identified and quantified various flavanols in jambolan fruit pulp. These flavanols include myricetin 3-O-glucoside, syringetin 3-O-galactoside, myricetin 3-O-pentose, myricetin 3-O-rhamnose, syringetin 3-O-glucoside, myricetin 3-O-glucuronide, laricitrin 3-O-glucoside, laricitrin 3-O-galactoside, and myricetin 3-O-galactoside. The respective quantities of these flavanols were determined to be 30.31, 17.74, 11.55, 10.64, 8.92, 7.53, 5.82, 5.00, and 2.50 mg kg^-1 fresh weight (FW). In contrast, Tavares et al. (2016) identified several flavanols in the peel of jambolan fruit, including myricetin 3-O-glucoside, myricetin 3-O-rhamnose, myricetin 3-O-glucuronide, laricitrin 3-O-glucoside, myricetin 3-O-pentose, syringetin 3-O-glucoside, syringetin 3-O-galactoside, myricetin 3-O-

galactoside, and laricitrin 3-O-galactoside. The respective concentrations of these flavanols were reported as 64.4, 11.92, 8.0, 5.04, 3.21, 2.13, 1.91, 1.76, and 1.62 mg kg-1 FW.

The extent or level of phenolic compounds which provides resistance against diseases:

The peel of the jambolan fruit exhibited a considerably higher total phenolic content (TPC) compared to the combined TPC of the pulp and seed. According to Bajpai et al. (2005), the jambolan seed crude extract contains ellagic acid (38 µg/g), gallic acid (646 µg/g), quercetin (98 µg/g), and kaempferol (59 µg/g). According to Aqil et al. (2012), the amounts of total phenolic compounds (TPC) in jambolan pulp and seed powder are 1.15 percent and 2.69 percent, respectively. In their study, Arun et al. (2011) documented the total phenolic compound (TPC) concentrations in various solvents. The TPC concentrations were found to be 16,833 mg GAE/100 g in water, 47,167 mg GAE/100 g in ethanol, 23,000 mg GAE/100 g in acetone, and 37,500 mg GAE/100 g in ethyl acetate. The study conducted by Mohamed et al. (2013) found that the methanolic and methylene chloride extracts of Jambolan leaf contained 1403 and 655 mg GAE/100 g DW of total phenolic compounds (TPC), respectively. According to Brandrao et al. (2011), the phenolic components in jambolan fruit were shown to be more abundant at the unripe stage, but their concentration dropped as the fruit underwent ripening.

Acknowledgments: We thank all the resources helped us to learn and write the article on bioactive compounds in jamun

Declaration of Conflict of Interest

The authors declare that they have no conflict of interest.

References

Afify, A.E.M.M., Fayed, S.A., Shalaby, E.A. & El-Shemy, H.A. (2011). Syzygium cumini (pomposia) active principles exhibit potent anticancer and antioxidant activities. African Journal of Pharmacy and Pharmacology, 5, 948–956.

Ali, T.M., Abbasi, K.S., Ali, A. & Hussain, A. (2015). Some compositional and biochemical attributes of jaman fruit (*Syzygium cumini* L.) from Potowar region of Pakistan. Research in Pharmacy, 3, 1–09.

Aqil, F., Gupta, A., Munagala, R. et al. (2012). Antioxidant and antiproliferative activities of anthocyanin/ellagitannin-enriched extracts from Syzygium cumini L. (Jamun, the Indian Blackberry). Nutrition and Cancer, 64, 428–438.

Aqil, F., Jeyabalan, J., Munagala, R., Singh, I.P. & Gupta, R.C. (2016). Prevention of hormonal breast cancer by dietary jamun. Molecular Nutrition & Food Research, 60, 1470–1481.

Aqil, F., Munagala, R., Jeyabalan, J., Joshi, T., Gupta, R.C. & Singh, I.P. (2014). The Indian Blackberry (Jamun), Antioxidant Capacity, and Cancer Protection. In Cancer (pp. 101–113).

Arun, R., Prakash, M.V.D., Abraham, S.K. & Premkumar, K. (2011). Role of *Syzygium cumini* seed extract in the chemoprevention of in vivo genomic damage and oxidative stress. Journal of Ethnopharmacology, 134, 329–333.

Ayyanar, M. & Subash-Babu, P. (2012). *Syzygium cumini* (L.) Skeels: A review of its phytochemical constituents and traditional uses. Asian Pacific Journal of Tropical Biomedicine, 2, 240–246.

Bajpai, M., Pande, A., Tewari, S.K. & Prakash, D. (2005). Phenolic contents and antioxidant activity of some food and medicinal plants. International Journal of Food Sciences and Nutrition, 56, 287–291.

Baliga, M.S., Bhat, H.P., Baliga, B.R.V., Wilson, R. & Palatty, P.L. (2011). Phytochemistry, traditional uses and pharmacology of *Eugenia jambolana* Lam. (black plum): a review. Food Research International, 44, 1776–1789.

Banerjee, A., Dasgupta, N. & De, B. (2005). In vitro study of antioxidant activity of *Syzygium cumini* fruit. Food Chemistry, 90, 727–733.

Barh, D. & Viswanathan, G. (2008). *Syzygium cumini* inhibits growth and induces apoptosis in

cervical cancer cell lines: a primary study. Ecancermedicalscience, 2, 83.

Benherlal, P.S. & Arumughan, C. (2007). Chemical composition and in vitro antioxidant studies on *Syzygium cumini* fruit. Journal of the Science of Food and Agriculture, 87, 2560–2569.

Bhowmik, D., Gopinath, H., Kumar, B.P. & Kumar, K. (2013). Traditional and medicinal uses of Indian black berry. Journal of Pharmacognosy and Phytochemistry, 1, 36–41.

Branco, I.G., Moraes, I.C.F., Argandona, E.J.S. ~ et al. (2016). Influence of pasteurization on antioxidant and in vitro anti-proliferative effects of jambolan (*Syzygium cumini* (L.) Skeels) fruit pulp. Industrial Crops and Products, 89, 225–230.

Eshwarappa, R.S.B., Iyer, R.S., Subbaramaiah, S.R., Richard, S.A. & Dhananjaya, B.L. (2014). Antioxidant activity of Syzygium cumini leaf gall extracts. BioImpacts: BI, 4, 101.

Faria, A.F., Marques, M.C. & Mercadante, A.Z. (2011). Identification of bioactive compounds from jambol~ao (Syzygium cumini) and antioxidant capacity evaluation in different pH conditions. Food Chemistry, 126, 1571–1578.

Fracassetti, D., Costa, C., Moulay, L. & Tomas-Barberan, F.A. (2013). Ellagic acid derivatives, ellagitannins, proanthocyanidins and other phenolics, vitamin C and antioxidant capacity of two powder products from camu-camu fruit (Myrciaria dubia). Food Chemistry, 139, 578–588.

Frauches, N.S., do Amaral, T.O., Largueza, C.B.D. & Teodoro, A.J. (2016). Brazilian myrtaceae fruits: a review of anticancer proprieties. British Journal of Pharmaceutical Research, 12, 1–15.

Ghosh, D., Banerjee, R. & Salimath, B.P. (2017). Suppression of VEGF-induced angiogenesis and tumor growth by Eugenia jambolana, Musa paradisiaca, and Coccinia indica extracts. Pharmaceutical Biology, 55, 1489–1499.

Jagetia, G.C., Shetty, P.C. & Vidyasagar, M.S. (2008). Treatment of mice with leaf extract of jamun (*Syzygium cumini* linn. Skeels) protects against the radiation-induced damage in the intestinal mucosa of mice exposed to different doses of c-radiation. Pharmacology, 1, 169–195.

Jain, A., Sharma, S., Goyal, M. et al. (2010). Anti-inflammatory activity of *Syzygium cumini* leaves. International Journal of Phytomedicine, 2, 124–126.

Kumar, A., Ilavarasan, R., Jayachandran, T. et al. (2008). Antiinflammatory activity of Syzygium cumini seed. African Journal of Biotechnology, 7, 941–943.

Kusumoto, I.T., Nakabayashi, T., Kida, H. et al. (1995). Screening of various plant extracts used in ayurvedic medicine for inhibitory effects on human immunodeficiency virus type 1 (HIV-1) protease. Phytotherapy Research, 9, 180–184.

Lestario, L.N., Howard, L.R., Brownmiller, C., Stebbins, N.B., Liyanage, R. & Lay, J.O. (2017). Changes in polyphenolics during maturation of Java plum (Syzygium cumini Lam.). Food Research International, 100, 385–391.

Li, L., Adams, L.S., Chen, S., Killian, C., Ahmed, A. & Seeram, N.P. (2009). Eugenia jambolana Lam. berry extract inhibits growth and induces apoptosis of human breast cancer but not non-tumorigenic breast cells. Journal of Agricultural and Food Chemistry, 57, 826–831.

Maria do Socorro, M.R., Alves, R.E., de Brito, E.S., Perez-Jimenez, J., Saura-Calixto, F. & Mancini-Filho, J. (2010). Bioactive compounds and antioxidant capacities of 18 non-traditional tropical fruits from Brazil. Food Chemistry, 121, 996–1002.

Mastan, S.K., Chaitanya, G., Latha, T.B., Srikanth, A., Sumalatha, G. & Kumar, K.E. (2009). Cardioprotective effect of methanolic extract of Syzygium cumini seeds on isoproterenol-induced myocardial infarction in rats. Der Pharmacia Lettre, 1, 143–149.

Miyazawa, T., Nakagawa, K., Kudo, M., Muraishi, K. & Someya, K. (1999). Direct intestinal absorption of red fruit anthocyanins, cyanidin-3-glucoside

and cyanidin-3, 5-diglucoside, into rats and humans. Journal of Agricultural and Food Chemistry, 47, 1083– 1091.

Parmar, J., Sharma, P., Verma, P. & Goyal, P.K. (2010). Chemopreventive action of Syzygium cumini on DMBA-induced skin papillomagenesis

Raffaelli, F., Borroni, F., Alidori, A. et al. (2015). Effects of in vitro supplementation with Syzygium cumini (L.) on platelets from subjects affected by diabetes mellitus. Platelets, 26, 720–725.

Ramirez, R.O. & Roa, C.C. Jr. (2003). The gastroprotective effect of tannins extracted from duhat (Syzygium cumini Skeels) bark on HCl/ethanol induced gastric mucosal injury in Sprague-Dawley rats. Clinical Hemorheology and Microcirculation, 29, 253–261.

Ravi, K., Rajasekaran, S. & Subramanian, S. (2005). Antihyperlipidemic effect of Eugenia jambolana seed kernel on streptozotocin-induced diabetes in rats. Food and Chemical Toxicology, 43, 1433–1439.

Ravi, K., Sivagnanam, K. & Subramanian, S. (2004). Anti-diabetic activity of Eugenia jambolana seed kernels on streptozotocin induced diabetic rats. Journal of Medicinal Food, 7, 187–191.

Reginold, J.S. & Jeyanth, A.S. (2016). Antioxidant activity, total phenol, flavonoid, and anthocyanin contents of jamun (Syzygium cumini) pulp powder. Asian Journal of Pharmaceutical and Clinical Research, 9, 361–363.

Reynertson, K.A., Yang, H., Jiang, B., Basile, M.J. & Kennelly, E.J. (2008). Quantitative analysis of antiradical phenolic constituents from fourteen edible Myrtaceae fruits. Food Chemistry, 109, 883–890.

Tavares, I.M.d.C., Lago-Vanzela, E.S., Rebello, L.P.G. et al. (2016). Comprehensive study of the phenolic composition of the edible parts of jambolan fruit (*Syzygium cumini* (L.) Skeels). Food Research International, 82, 1–13.

Tavares, I.M.d.C., Nogueira, T.Y.K., Mauro, M.A. et al. (2017). Dehydration of jambolan [*Syzygium cumini* (L.)] juice during foam mat drying: quantitative and qualitative changes of the phenolic compounds. Food Research International, 102, 32–42.

Treutter, D. (2010). Managing phenol contents in crop plants by phytochemical farming and breeding—visions and constraints. International Journal of Molecular Sciences, 11, 807–857.

Veigas, J.M., Narayan, M.S., Laxman, P.M. & Neelwarne, B. (2007). Chemical nature, stability and bio-efficacies of anthocyanins from fruit peel of *Syzygium cumini* Skeels. Food Chemistry, 105, 619– 627.

Villasenor, I.M. & Lamadrid, M.R.A. (2006). Comparative antihyperglycemic potentials of medicinal plants. Journal of Ethnopharmacology, 104, 129–131.

Zhang, L.L. & Lin, Y.M. (2009). Antioxidant tannins from *Syzygium cumini* fruit. African Journal of Biotechnology, 8, 2301–2309.

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Nanotechnology: A Potential Alternative for Plant Disease Management

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Nanotechnology is a growing interdisciplinary science in the past decades that links knowledge of biology, chemistry, physics, engineering, and material science. Application of nanotechnology in crop protection is of relatively recent origin compared with its use in drug delivery and pharmaceuticals. Any material when attenuated at nanometer scale (less than 100 nm) exhibits new properties that are entirely different from its bulk counterpart due to small size and high surface to volume ratio. Material scientists have engineered nanoparticles with desired characteristics, like shape, pore size, and surface properties, so that they can then be used as protectants or for precise and targeted delivery via adsorption, encapsulation, and/or conjugation of an active, such as a pesticide. Nanosensors and other field sensing devices can be used in detection and measurement of crop nutrient status, insects, and pathogens. Nanomaterial is used in plant protection through controlled release of encapsulated pesticide against pests and pathogens. Nanoparticles remain bound to the cell wall of pathogen and causes deformity due to high energy transfer leading to its death. Nanotechnology has tremendous potential in existing and future crop improvement programs through plant protection strategies against pests and diseases, in monitoring pathogens, and in detecting plant diseases. Researchers believe that agricultural production is one of the most important fields for application of nanotechnology.

Application of various nanoparticles for management of plant disease

Silver NPs

Silver (Ag) is known to have antimicrobial activity both in ionic or nanoparticle forms. The powerful antimicrobial effect of silver especially in unicellular microorganisms is believed to be brought about by enzyme inactivation (Kim et al., 1998). Nano silver whose antimicrobial effect has been tested against many disease causing pathogens of animals and plants is the most studied and utilized nanoparticle. Silver is also an excellent plant growth stimulator. Antifungal effect of nano silver colloids (average diameter of 1.5 nm) was studied against the powdery mildew pathogen of rose caused *by Sphaerotheca pannosa* var. *rosae.* Silver is now an accepted agrochemical replacement' and maximum no. of patents are filed for 'nano silver' for preservation and treatment of diseases in agriculture field (Sharon *et al*., 2010). Application of silver in management of plant diseases has been tested by (Jo *et al*., 2009) with reference to two fungal pathogens of cereals viz. *Bipolaris sorokiniana* (spot blotch of wheat) and *Magnaporthe grisea* (rice blast).

In vitro assays indicated that silver both in ionic and nanoparticle forms inhibited colony growth of both the pathogens but M. *grisea* was comparatively more sensitive to silver application. When tested in vivo with perennial ryegrass *(Lolium perenne*) silver ions and nanoparticles brought significant reduction in disease severity when applied 3 hours prior to pathogen inoculation. In another study, silver nano particles synthesized extracellularly by *Alternaria alternata* were found to cause significant enhancement in the antifungal action of the triazole fungicide fluconazole against *Candida albicans, Phoma glomerata* and *Trichoderma* sp. (Gajbhiye *et al*., 2009). However, no significant enhancement was observed with respect to the fungi *Phoma herbarum* and *Fusarium semitectum*. The effect of silver nanoparticles on plant pathogenic fungi and bacteria is given in table 1 and table 2 respectively.

Copper nanoparticle

Copper-based fungicides produce highly reactive hydroxyl radicals which can damage lipids, proteins, DNA, and other biomolecules. It plays an important role in disease prevention and treatment of large variety of plants. Nano-copper was reported to be highly effective in controlling bacterial diseases viz. bacterial blight of rice (*Xanthomonas oryzae pv.oryzae*) and leaf spot of mung (*X. campestris pv. phaseoli*) (Gogoi *et al.,* 2009). Copper nanoparticles in soda lime glass

powder showed efficient antimicrobial activity against gram positive and gram negative bacteria and fungi.

Table 1. Effect of Ag nanoparticles on plant pathogenic fungi (Khan and Rizi, 2019)

NP size	Plant pathogen	Effect
20–30 nm	*Bipolaris sorokiniana, Magnaporthe grisea*	Inhibited colony formation (in vitro)
7-25 nm	*A. alternate, A. brassicicola, A. solani, B. cinerea, Cladosporium cucumerinum, Corynespora cassiicola, Cylindrocarpon destructans, Didymella bryoniae, F. oxysporum, Fusarium oxysporum* f. sp. *cucumerinum, F. Oxysporum* f. sp. *lycopersici, F. solani, Glomerella cingulata, Monospora scuscannonballus, Pythium aphanidermatum, Pythium spinosum, Stemphylium lycopersici*	Inhibition in the microbial growth
25 nm	*Golovinomyces cichoracearum, Sphaerotheca fusca*	Disrupted the transport systems and ion efflux
5–20 nm	*Trichosporonasahii*	Damaged the cell wall, cell membrane, mitochondria, chromatin, and ribosome
4-8nm	*R. solani, Sclerotium sclerotiorum, S. minor*	Separation of hyphal wall and collapse of hyphae

(Mondal and Mani, 2012) reported that copper nanoparticle effectively contolled *Xanthomonas axonopodis pv. pinicea*, causing blight in pomegranate. (Azam et al. 2012) reported the suppressive effect of CuO nanoparticle on *S. aureus, B. subtilis, P. aeruginosa* and *E. coli.* Effect of copper NPs on some plant pathogenic fungi is given in table 3.

Table 2. Effect of Ag nanoparticle on bacteria (Khan and Rizi, 2019)

NP size	Bacteria	Effect
35 nm	Bacteria	In vitro
35-550 nm	*Bacillus cereus, Listeria monocytogenes, Staphylococcus aureus, Escherichia coli, Salmonella*	Antibacterial Activity
13.8 ± 3.8 nm	*Staphylococcus aureus, E. coli, P. aeruginosa* and spore of *B. subtilis*	Bactericidal and sporocidic activity
300–800 nm	*E. coli, S. aureus, Proteus vulgaris*	Antibacterial Activity

Table 3: Effect of copper nanoparticles on plant pathogenic fungi (Khan and Rizi, 2019)

NP size	Plant pathogen	Effect
11-55 nm	*Phytophthora infestans*	Antifungal activity
3- 30 nm	*F. culmorum, F. oxysporum, F. equiseti*	Antifungal activity
3-10 nm	*F. oxysporum, C. lunata, A. Alternate, P. destructive*	Antifungal activity

Zinc nanoparticle

Zinc oxide nanoparticles (ZnO NPs) could be used as an effective fungicide in agricultural and food safety applications. (Prasun Patra. and Goswami, 2012) reported that mechanism of action of zinc nitrate derived nano-ZnO on *Aspergillus fumigatus* showed hydroxyl and superoxide radicals mediated fungal cellwall deformity and death due to high energy transfer.

Table 4. Effect of Zn nanoparticles on plant pathogenic fungi (Khan and Rizi, 2019)

Nano particle	NP size (in nm)	Plant pathogen	Effect
Zn	57.72	*A. flavus, A. niger, . albicans*	Antifungal activity
Zn		*Aspergillus niger*	Antifungal activity
ZnO	20- 35	*Erythricium salmonicolor*	Antifungal activity
ZnO	70 ± 15 nm	*B. cinerea, Penicillium expansum*	Prevented the development of conidiophores and conidia

ZnO NPs have also been reported to cause antifungal activity against *Botrytis cinerea* and *Penicillium expansum* at 12 mmol l−1. The ZnO NPs at a concentration of 3 mmol l−1 significantly inhibited the growth of *B. cinerea* and *P. Expansum,* later was more sensitive to the treatment with ZnO NPs than *B. cinerea*. SEM images and Raman spectra indicated that ZnO NPs caused deformation in fungal hyphae and prevented the development of conidiophores and conidia (He *et al.,* 2011). More research outcome of Zn nanoparticles effect on plant pathogenic fungi and bacteria are shown in table 4 and table 5.

Chitosan

Chitosan nanoparticles have got various applications in biology due to its biodegradable and nontoxic properties. In acidic condition the free amino groups of chitosan protonates and contributes to its positive charge (Phaechamud and Ritthidej, 2008). The inhibition mode of chitosan against fungi is defined by the following three mechanisms.

i) The positive charge of chitosan interacts with negatively charged phospholipid components of fungi membrane, which in turn alter cell permeability of plasma membrane and causes the leakage of cellular contents, which consequently leads to death of the cell (García- Rincón *et al*., 2010).

Table 5, Effect of Zn nanoparticle on Bacteria (Khan and Rizi, 2019)

Nano particle	NP size (nm)	Bacteria	Effect
ZnO	**13**	*E. coli, S. aureus*	Inhibited the microbial growth
Zn	**57-72**	*A. hydrophila, E. coli, S. aureus, E. faecalis, S. pyogenes, P. aeruginosa*	Antibacterial activity
Zn	<100 nm	*Campylobacter jejuni*	Change cell morphology to lethal
ZnO suspension	≤50 nm	*Salmonella typhimurium, Staphylococcus aureus*	Antibacterial (in vitro)
ZnO	**50-70**	*S. epidermis, S. pyogenes, Enterococcus faecalis, B. subtilis, E. coli*	Caused higher antibacterial activity on *S. aureus*
ZnO	**19.82**	Methicillin-susceptible *Staphylococcus aureus* (MSSA), methicillin-resistant *S. aureus* (MRSA), methicillin-resistant *S. epidermidis* (MRSE)	Inhibited bacterial growth of MSSA, MRSA and MRSE strains
ZnO	**60-100**	*Streptococcus agalactiae, S. aureus*	Bactericidal action

ii) Chitosan chelates with metal ions, which has been implicated as a possible mode of antimicrobial action (Rabea *et al*., 2003). On binding to trace elements, it interrupts normal growth of fungi by making the essential nutrients unavailable for its development (Roller and Covill, 1999).

iii) It is suggested that chitosan could penetrate fungal cell wall and bind to its DNA and inhibit the synthesis of mRNA and, in turn, affect the production of essential proteins and enzymes (Kong *et al*., 2010).

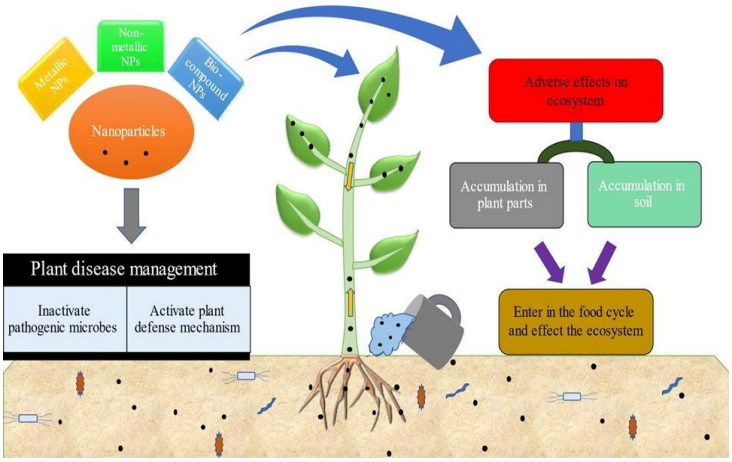

Fig 1: Mechanisim of nanoparticles in disease management (Rajani *et al.* 2022)

chitosan and chitosan nanoparticles are found to be more effective against plant pathogens like *Fusarium solani*. Inhibitory effect was also influenced by particle size and zeta potential of chitosan nanoparticles which plays a significant role in binding with negatively charged microbial membrane. The chitosan therefore could be formulated and applied as a natural antifungal agent in nanoparticles form to enhance its antifungal activity.

Conclusion

Nanotechnology in conjunction with biotechnology has significantly extended the applicability of nanomaterials in crop protection and production. Even though the toxicity of nanomaterials has not yet clearly understood, it plays a significant role in crop protection because of its unique physical and chemical properties. The application of nanomaterials is relatively new in the field of agriculture and it needs further research investigations. Barring the miniscule limitations, nanomaterials have a tremendous potential in making crop protection methodologies cost effective and environmental friendly.

References

Azam, A., Ahmed, A. S., Oves, M., Khan, M. S., Habib, S. S., & Memic, A. (2012). Antimicrobial activity of metal oxide nanoparticles against Gram-positive and Gram-negative bacteria: a comparative study. International journal of nanomedicine, 6003-6009.

Gajbhiye, M., Kesharwani, J., Ingle, A., Gade, A., & Rai, M. (2009). Fungus-mediated synthesis of silver nanoparticles and their activity against pathogenic fungi in combination with fluconazole. *Nanomedicine: Nanotechnology, Biology and Medicine*, **5**(4), 382-386.

Garcia Rincon, J., Vega Perez, J., Guerra Sinchez, M.G., Hernndez Lauzardo, A.N., Peqa Diaz, A., Velizquez Del Valle, M.G., 2010. Effect of chitosan on growth and plasma membrane properties of *Rhizopus stolonifer* (Ehrenb.:Fr.) Vuill. Pesticide Biochemistry and Physiology, **97**(3): 275-278.

He, L., Liu, Y., Mustapha, A. and Lin, M. 2011.Antifungal activity of zinc oxide nanoparticles against *Botrytis cinerea* and *Penicillium expansum*. *Microbiological Research*, **166**: 207-215.

Jo, Y.K., Kim B.H. and Jung, G. (2009). Antifungal Activity of Silver Ions and Nanoparticles on Phytopathogenic Fungi. Plant Dis. **93**(10): 1037-43.

Khan, M.R., Ahamad, F., Risvi, T.F.(2019). Effect of nanoparticles on plant pathogen. Advances in phytonanotechnology. Elsevier. Newyork. pp 215- 240.

Kim, T.N., Feng, Q.L., Kim, J.O., Wu, J., Wang, H., Chen, G.C. and Cui, F.Z. (1998). Antimicrobial effects of metal ions (Ag+, Cu2+, Zn2+) in hydroxyapatite. J. Mater. Sci. Mater. Med. **9**: 129-134.

Kong, H., Song, J. and Jang, J. (2010). Photocatalytic antibacterial capabilities of TiO2− biocidal polymer nanocomposites synthesized by a surface-initiated photopolymerization. *Environmental science & technology*, **44**(14), 5672-5676.

Mondal, K. and Mani, C. 2012. Inves tigation of the antibacterial propert ies of nanocopper against *Xanthomonas axonopodis* pv. *punicae*, the incitant of pomegranate bacterial blight. Annals of Microbiology, **62:** 889-893.

Patra, P. and Goswami, A. (2012). Zinc nitrate derived nano ZnO: fungicide for disease management of horticultural crops. International journal of innovative horticulture, **1**(1), 79-84.

Phaechamud, T. and Rit thidej, G. C. 2008. Formulation variables influencing drug release from layered matrixsystem comprising chitosan and xanthan gum. *AAPS Pharm SciTech*, **9**: 870-877.

Rabea, E. I., Badawy, M. E. T., Stevens, C. V., Smagghe, G. and Steurbaut, W. 2003. Chitosan as Antimicrobial Agent: Applications and Mode of Action.*Biomacromolecules*, **4** : 1457-1465.

Rajani, P. M., Kumari, S., Saini, P., & Meena, R. K. (2022). Role of nanotechnology in management of plant viral diseases. Material Today: Proceedings https://doi.org/10.1016/j.matpr.2022.06.355

Roller, S. and Covill, N. 1999.The antifungal propert ies of chitosan in laboratory media and apple juice. *Internat ional Journal of Food Microbiology*, **47**:67-77.

Saikia, J., Gogoi, A., & Baruah, S. (2019). Nanotechnology for water remediation. *Environmental Nanotechnology:* **2**, 195-211.

Sharon, M., Choudhary, A.K. and Kumar, R**.** (2010). Nanotechnology in agricultural diseases and food safety. J. Phytology ,**2**(4): 83-92.

Worrall, E.A., Hamid, A., Mody, K.T. Mitter, N. and Pappu, H.R. (2018). Nanotechnology for plant disease management. Agronomy, (8). 285.

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Major Pests of Winter Vegetable Crops

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India is growing 12 per cent of the world's vegetable. The different vegetable crops are grown in different seasons (spring, summer, autumn, winter) of the year. Among the winter vegetables, cruciferous crops (potato, pea, broccoli, brussels sprouts, cabbage, cauliflower, collards, mustard, turnip, radish, kale, bok-choy and kohlrabi) are most important. These vegetable crops are mostly cultivated at mild temperature with relative humidity (50-70 %). These climatic conditions are very conducive for development and survival of insect-pests and diseases. Since winter vegetable crops are highly remunerative, intensive plant protection measures involving a number of pesticides are very common. In spite of large scale and indiscriminate use of insecticides, the pests have been found to occur in severe form in all vegetable crops. In recent years, there is a lot of awareness and preference for organically produced foodstuff in the country. Therefore, ecofriendly pest management has gained worldwide attention. This technology is not only effective against vegetable pests but also safer to human health, beneficial insects and environment

Insect-pests

Butterflies: *Pieris brassicae nepalensis* (large cabbage white) and *Pieris canidia indica* (common cabbage white) are found everywhere in our country. The butterflies are small to medium size and numerously available especially during winter and spring seasons. The body is decorated with short hairs. The wings pale white, with black patch on apical angle of each forewing and black spot on the costal margin of each hind wing. These butterflies are responsible for severe destruction of cole crops, at plantlets stage and in mature crop. The butterflies larvae making, the conditions hell for vegetable crops by making the holes in greens leaves and shoots of the plants. The larvae excrete their faecal matters on leaves and flowers, which also reduced market price of vegetables.

Diamond back moth (*Plutella xylostella*): The moth is small-medium in size with wing-spans 7 - 55 mm. The wings are prolonged and hind wings bear black frills at the margins. The fore-wings often emerge to be sickle-shaped because positioning of the frills. The adults are mostly dusky in color and night-loving in habit. The larvae feed on upper layering of leaves, which they make like bare bones. The insect feed and shelter on all winter vegetable crops.

Aphid (*Brevicoryne brassicae*): It damages all vegetable crops by sucking cell sap from tender leaves/shoots. The infested plants have stunted growth and poor head formation. Under severe infestation, the entire plant may dry up. If damage occurred in nursery the infested seedlings lose their vigour, gets distorted and become unfit for transplanting. Aphids also excrete honeydew on leaves, which attracts sooty moulds fungus and reduces the photosynthetic activities of plants. The aphids cause heavy losses both in yield and in quality of crop produce. The nymphs are 1-1.5 mm long and yellow green with light ash grey tin, however adults are about 2 mm in length and ash grey in colour. The aphids are active from October to April and have many generations.

Cabbage semilooper (*Thysanoplusia orichalcea)*: This pest feed and multiplies in all cole crops. The larva is plump and pale green having three pairs of prolegs generally resembled with the caterpillars of *P brassicae*. Adults are light brown with a golden patch on each forewing and measures about 42 mm with wingspan and very active at dusk. The insect larvae cause the damage by biting round holes into the leaves and the biting holes of varying size depending on the larval instars.

Cabbage head borer (*Hellula undalis*): It is also a serious pest of all cruciferous crops. The caterpillars are creamy yellow with a pinkish tinge and have seven purplish brown longitudinal stripes. The caterpillars first mine into leaves and feed on the chlorophyll.

Later on feed on the leaf surface sheltered within the silken passage. As the caterpillars grow in size, they bore into the heads of cabbage and cauliflower. In heavy infestation, the plants are riddled with caterpillars. Moths are slender, pale yellowish-brown, having grey wavy lines on the fore wings and hind wings are pale dusky.

Tobacco caterpillar (*Spodoptera litura)*: It is polyphagous in nature and caterpillar feeds on younger leaves (new growth). The young larvae feed gregariously initially and make holes on leaves. The older larvae defoliate entire foliage. The full-grown larva is about 35-40 mm in length with velvety black, yellowish green dorsal strips and lateral white bands. The moths are about 22 mm in length and 40 mm across the wings.

Cutworms (*Agrotis ipsilon):* The larvae may cut off the stems of young plants during stand establishment. Later in the season, they feed on foliage. Tubers that are exposed on the soil, or by cracks, or are set very shallow may be damaged. Cutworm damage to tubers appears as a gouged-out cavity.

Diseases

Potato Late blight *(Phytophthora infestans)***:** The Infected tubers from cold stores serve as primary source of disease. The sprouts and leaves are infected. The water-soaked spots appear on margins of leaves which later turn into black patches with whitish fungus growth visible on lower surface in the morning hours. Black patches may extend and kill the foliage in a few days if moist weather prevails. Decaying leaves emit an offensive odour.

Black scurf of potato: *(Rhizoctonia solani).* The disease is easily recognised by raised hard, black patches, irregular in size or shape on the surface of the tuber. The infested tubers have black rough incrustations. The crop grown from diseased tubers show wilting.

Pea powdery mildew *(Erysiphe polygoni*): The white floury patches covering large areas appear on stem, branches, leaves and pods.

Rust *(Uromyces viciae fabae)*: The late sown crop is more infested. The yellowish, reddish-brown, spherical, raised pustules appear mainly on the lower side of leaves during December-January.

Damping off *(Pythium sp., Rhizoctonia sp.* and *Fusarium sp.)*: The pre and post emergence death of seedlings occurs

Alternaria blight (*Alternaria brassicae and A. brassicicola*): The concentric spots appears on the lower leaves. The curd also gets infected and rots. Brown spots are formed on pods in the seed crop.

Downy mildew *(Peronospora parasitica):* The disease develops on leaves and curds. On leaves, the lesions are yellowish, irregular to angular with white 'downy' growth. The curd tops turn brown. The stems develop dark brown depressed irregular lesions/streaks with whitish 'downy' growth. The severely infected curds rot and fail to produce seeds.

Integrated Management:

1) Do clean cultivation deep ploughing in summer months for exposure of larvae/pupae to sun and predatory bird.
2) Remove and destroy the crop debris, stubbles etc.
3) Use healthy disease free seed/tubers.
4) Do intercropping of cole crops with tomato, lavender, marigold and mint crops to distract the insect-pests from infesting main crops.
5) Grow African bold seeded mustard as capture crop, 22 cabbage plants for 2 mustard plants to attract diamond back moth for spawning at least 12-10 days ahead of planting of main crop.
6) Monitoring of pest population at seedling or early growth stage.
7) Hand picking and mechanical destruction of eggs and larvae in early stage of damage can reduce pest infestation. For aphids**:** cut and destroy the infested leaves/shoots mechanically as soon as the aphid attack appears.

8) Predators like coccinellids, syrphids and chrysopids; and parasitoids like *Aphidius* spp also reduce the aphid population. Therefore, need to enhance the population of natural enemies of pests.

9) Apply pheromone traps to predict egg laying of lepidopterous pests.

10) Application of homemade neem extract @ 2.0 litres in 100 litres of water per acre may also reduce the incidence of sucking pests of vegetable crops. (Preparation of homemade neem extract: boil 4 kg leaves/tendril shoots of neem trees in 10 litres of water for 30 minutes, cool this solution then filtered with muslin cloth). Potato blight

11) Use selected healthy tubers for planting and follow high ridge culture to avoid tuber infection of late blight. Spray the crop with 500-700 g Antracol/Indofil M-45/Mass M-45/Markzeb/Kavach or 750-1000 g Copper oxychloride 50 WP/Mark copper per acre in 250-350 litres of water in the first week of November before the appearance of disease followed by 5 more sprays at 7 days interval. Under heavy disease risk situation instead of 3rd and 4th spray of Indofil M-45/Mass M-45/Markzeb/Kavach/Antracol, give two sprays of 700 g Melody Duo 66.75 WP or Ridomil Gold or Sectin 60 WG or Curzate M-8 or 250 ml Revus 250 SC or 200 ml Equation Pro per acre at 10 days interval. Subsequently give one spray of Indofil M-45/Kavach/Antracol for late blight of potato. In late/spring sown crop if the previous crop is infected and disease risk is heavy due to humid weather, give first spray of 500 g Melody Duo 66.75 WP or Ridomil Gold/Sectin 60 WG/Curzate M-8 or 250 ml Revus 250 SC or 200 ml Equation Pro per acre followed by three sprays of 700 g Indofil M-45/Mass M-45/Markzeb/Kavach/ Antracol per acre at 7 days interval.

12) Disinfect the tubers with 83 ml Emesto Prime 22.43 FS or 250 ml Moncoren 250 SL in 100 litres water for ten minutes or Dip potato seed tubers in 10 g wet *Trichoderma* formulation and 20 g molasses per litre water for 10 minutes. Keep treated seed in shade for 24 hours before sowing against potato scurf.

13) Spray the crop with 200g Sulfex in combination with 400 g Indofil M-45 per acre for pea diseases.

14) Treat the seed before sowing with 3g of Captan per kg seed and drench the soil around the seedlings with 200g of Captan per 100 litres of water twice, viz. on the 7th & 15th days after sowing against damping off and spray the crop with 500g Indofil M-45 in 200 litres of water per acre at 7day intervals for alternaria blight disease.

15) Spray the crop with 500 g Indofil M-45 in 200 litres of water per acre at 7-day intervals for cole crops downy mildew.

Conclusion

It has been observed that the vegetables producers use indiscriminate pesticides for pest management that may create residue as a problem, health hazards and environmental contamination. Therefore, this article will create awareness among vegetable growers for identification of different pests, their timely management and restriction of pesticide use.

Table 1: Major pests of vegetable crops

Pest	Symptoms	Pest	Symptoms
Cabbage butterfly		Late blight of potato	
Cabbage semilooper		Potato black scurf	
Cabbage head borer		Powdery mildew of pea	
Tobacco caterpillar		Downey mildew of cauliflower	

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Mycoviruses: Nature's Fungus-Fighting Allies

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Mycoviruses are a special class of viruses that have drawn interest from researchers because of their fascinating nature and possible usefulness. The word "mycovirus" comes from the word "myco" which means "fungus" signifying that these viruses only infect fungi (Mastigomycota, Zygomycota, Ascomycota and Basidiomycota). Mycoviruses have evolved to form symbiotic or antagonistic relationships with a variety of fungal hosts, unlike viruses that infect mammals or plants.

Based on the type of genome, the International Committee on Virus Taxonomy (ICTV) now classifies mycoviruses into 23 families and 1 unclassified genus. In terms of their genetic makeup and manner of operation, mycoviruses are different. Their sizes range greatly and they can have genomes made of single-stranded RNA (ss RNA) or double-stranded RNA (ds RNA). While some mycoviruses cause disease and impair their fungal hosts, others have been shown to have positive effects (Abdoulaye *et al.*, 2019).

Unveiling Nature's Specialized Fungus Viruses

Mycoviruses are a specialised niche within the fields of virology and mycology. When compared to viruses that infect other organisms, these viruses have adapted to flourish in the specific environment of fungi, which poses significant difficulties and opportunities. Understanding how mycoviruses interact with fungal hosts, particularly how they enter, multiply and propagate within fungal cells, is key to unravelling their secrets. Researchers are eager to learn more about the mechanisms underlying these interactions because they may hold the key to novel methods to disease control, biotechnology and ecology.

Surprisingly, some mycoviruses can form mutualistic interactions with fungi, assisting in nutrition acquisition or stress tolerance. Others, on the other hand, act as pathogens, causing illnesses in economically and environmentally significant fungi. The scientific community acquire insights into the delicate balance between viruses and their fungal hosts by investigating mycoviruses, giving light on the larger principles of virus-host interactions in the natural world.

Mycoviruses play an important role in disease control in a variety of ecosystems, particularly agriculture and forestry. Because of their potential to resist fungal infections that can ruin crops and forests, they are considered natural fungicide alternatives. Mycoviruses, as opposed to chemical fungicides, provide an environmentally benign and sustainable alternative to disease treatment.

Role of Mycoviruses in Disease Control

When a mycovirus infects a pathogenic fungus, it can disturb the fungus normal functioning in many ways. Some mycoviruses, for example, can disrupt the fungal pathogens reproduction, decreasing its ability to create spores or infect new hosts. Others can inhibit pathogen development and metabolism, rendering it less virulent. This weakening effect is known as "hypovirulence."

Cryphonectria hypovirus 1 (CHV1) is one of the most intriguing instances of a mycovirus that can be employed to control disease. CHV1 induces hypovirulence in its fungal host, *Cryphonectria parasitica*, which causes chestnut blight. Chestnut blight is a deadly disease that has wiped out billions of American chestnut trees. CHV1 can be transmitted to other *C. parasitica* individuals by hyphal anastomosis or the union of hyphae from separate fungal individuals.

In some places, CHV1 has been used successfully to control chestnut blight. In Italy, for example, CHV1 has been employed to rehabilitate disease-ravaged chestnut woods. In the United States, CHV1 is also used to control chestnut blight (Romon-Ochoa *et al.*, 2023).

Other mycoviruses that have been shown to have potential for disease control include:

- *Sclerotinia sclerotiorum* hypovirus 1 (SsHV1): SsHV1 causes hypovirulence in its fungal host, *Sclerotinia sclerotiorum*, which is a fungus that causes a variety of plant diseases, including white mold and sclerotinia stem rot (Longkumer, and Ahmad, 2020).
- *Rosellinia necatrix* hypovirus 1 (RnHV1): RnHV1 causes hypovirulence in its fungal host, *Rosellinia necatrix*, which is a fungus that causes white root rot of avocado trees (Chiba *et al.*, 2009).
- *Ophiostoma novo-ulmi* hypovirus 1 (OnHV1): OnHV1 causes hypovirulence in its fungal host, *Ophiostoma novo-ulmi*, which is a fungus that causes Dutch elm disease (Kotta-Loizou, 2021).

Biotechnological potential of Mycoviruses

Mycoviruses are a fast expanding topic of research with important implications for a variety of industries and scientific advances. They provide distinct advantages for a wide range of biotechnological applications including as genetic engineering tools, enzyme manufacturing, medicines and biological control. Mycoviruses have the ability to insert or change genes in fungal hosts, increasing productivity in industries such as biofuel manufacturing. They can also boost fungal enzyme synthesis, making them more efficient and cost-effective enzyme suppliers. Fungi are also a source of bioactive substances such as antibiotics and medicines, which mycoviruses can alter to boost production or develop new bioactive molecules with therapeutic promise. Mycoviruses can be utilised as biopesticides against fungal infections in agriculture, lowering their virulence and reducing the demand for chemical fungicides.

Utilising mycoviruses in biotechnology has implications for sustainable production, economic gains, scientific innovation and disease management. Mycoviruses can eliminate the need for resource-intensive and polluting alternatives by increasing the efficiency of fungi in industrial applications (Larios *et al.*, 2023). Mycoviruses also provide a unique platform for investigating virus-host interactions, evolution and genetic modification, all of which contribute to our understanding of fundamental biological processes.

Insights into Mycoviruses evolution

Although mycoviruses only infect fungus, they provide a unique perspective on virus evolution. They have a high level of genetic variety, with different lineages exhibiting distinct traits. Mycoviruses have evolved to take advantage of many characteristics of fungal biology, such as their cellular machinery and life cycles. They are susceptible to intense selective pressures imposed by their fungal hosts, forcing them to change in order to avoid or counter these defences. Mycoviruses coevolutionary association with their fungal hosts provides useful insights into wider aspects of viral evolution and host-pathogen relationships. An continual arms race, genetic adaptability, and horizontal gene transfer are all examples of this. Mycoviruses have the ability to undergo fast genetic alterations, allowing them to adapt to different environments and host defences. Horizontal gene transfer affects fungal evolution and adaptation (Sato and Suzuki, 2023).

Understanding the dynamics of fungal ecosystems requires a knowledge of mycovirus-fungus coevolution because interactions between these viruses and their hosts can affect the population structures, competitive dynamics and nutrient cycles of the fungi they infect. Strategies for controlling fungal diseases in forestry, agriculture and natural ecosystems can be influenced by the knowledge acquired from studying mycovirus-fungus coevolution. Researchers can create ground-breaking strategies for disease control by better understanding how mycoviruses interact with their fungus hosts. Mycovirus evolution offers a special viewpoint on the coevolutionary dynamics between viruses and their hosts, with applications in virology and ecological management, among other areas.

Applications in Agriculture and Forestry

Mycoviruses have demonstrated potential in forestry and agriculture, providing creative methods for controlling fungi that pose a threat to crop growth. These viruses have the potential to replace chemical fungicides by acting as natural biological control

agents against fungi that cause disease by lowering the frequency and severity of disease. Mycovirus-based disease management supports healthier and more resilient agricultural ecosystems and is consistent with sustainable agriculture concepts (Xie and Jiang, 2014).

In areas with a high reliance on agriculture, mycovirus techniques can also help lower yield losses in crops like wheat, rice and maize, boosting food security and economic stability. Mycovirus research in forestry is essential for maintaining forests and lessening the effects of fatal fungal infections. Mycoviruses, for instance, can be used to manage Dutch elm disease and the emerald ash borer, which both infect the fungus *Ophiostoma ulmi* (Adalia *et al.*, 2016).

By controlling fungal infections and preserving biodiversity, mycovirus research supports the maintenance of forest health. By shielding tree species from fungi, mycovirus-based techniques can also help sustainably produce lumber by maintaining a steady supply of high-quality wood products.

Challenges and Future Directions

Mycovirology is a growing discipline, however there are still many unanswered problems and challenges. These include mycovirus diversity across fungal species, transmission methods, coexistence tactics and the evolutionary dynamics of mycoviruses and fungi. Mycoviruses have a practical application in biotechnology and disease management, but it faces obstacles relating to delivery techniques, scalability and regulatory approval.

Despite these obstacles, mycovirology has a bright future thanks to new discoveries, biotechnology advances, ecological insights, disease management breakthroughs and fundamental virology. The research will identify novel mycoviruses with distinct features and possible applications, contributing to a better understanding of virus-fungus interactions. Biotechnology and genetic engineering advances will allow for more precise manipulation of mycoviruses and their fungal hosts, opening up new avenues for biotechnological applications.

Mycovirus research will provide light on nutrient cycling, fungal community dynamics and ecosystem health by providing greater insights into the role of viruses in fungal environments. Disease management technologies in agriculture and forestry have the potential to transform disease management practises, lowering dependency on chemical treatments and increasing sustainability.

Conclusion

Mycoviruses emerge as inconspicuous allies in nature's rich tapestry, acting behind the scenes to battle fungal threats. Mycoviruses, as specialised agents that only infect fungi, have opened up a new universe of possibilities and discoveries. They provide natural disease management alternatives in agriculture, lowering our dependency on chemical fungicides and supporting sustainable practises. Mycoviruses biotechnological potential opens the door to novel solutions in genetic engineering, enzyme synthesis and medicines. Their importance in moulding fungal ecosystems and nutrient cycle dynamics is highlighted by their function in ecological processes. Mycoviruses also provide an interesting look at virus evolution and virus-host interactions. In a world plagued by fungal infections and environmental degradation, mycoviruses serve as collaborators in fungus-fighting strategies, providing hope for a healthier, more robust future.

References

Abdoulaye, A.H., Foda, M.F. and Loizou, I.K. (2019). Viruses infecting the plant pathogenic fungus *Rhizoctonia solani*. Viruses, 11(12), 1113.

Adalia, E.J.M., Fernandez, M.M. and Diez, J.J. (2016). The use of mycoviruses in the control of forest diseases. Biocontrol Science and Technology, 26(5), 577-604.

Chiba, S., Salaipeth, L., Lin, Y.H., Sasaki, A., Kanematsu, S. and Suzuki, N. (2009). A novel bipartite double-stranded RNA mycovirus from the white root rot fungus *Rosellinia necatrix*: molecular and biological characterization, taxonomic considerations, and potential for

biological control. Journal of Virology, 83(24), 12801-12812.

Kotta-Loizou, I. (2021). Mycoviruses and their role in fungal pathogenesis. Current Opinion in Microbiology, 63, 10-18.

Larios, D.C.V., Reyes, B.M.D., Pirovani, C.P., Loguercio, L.L., Santos, V.C., Neto, A.G., Fonseca, P.L.C. and Aguiar, E.R.G.R. (2023). Exploring the mycovirus universe: identification, diversity, and biotechnological applications. Journal of Fungi, 9(3), 361.

Longkumer, I.Y. and Ahmad, M.A. (2020). Potential of mycovirus in the biological control of fungal plant pathogens: a review. Agricultural Reviews, 41(3), 238-247.

Romon-Ochoa, P., Smith, O., Lewis, A., Kupper, Q., Shamsi, W., Rigling, D., Perez-Sierra, A. and Ward, L. (2023). Temperature effects on the *Cryphonectria hypovirus* 1 accumulation and recovery within its fungal host, the chestnut blight pathogen *Cryphonectria parasitica*. Viruses, 15(6), 1260.

Sato, Y. and Suzuki, N. (2023). Continued mycovirus discovery expanding our understanding of virus lifestyles, symptom expression, and host defense. Current Opinion in Microbiology, 75, 102337.

Xie, J. and Jiang, D. (2014). New insights into mycoviruses and exploration for the biological control of crop fungal diseases. Annual Review of Phytopathology, 52, 45-68.

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Recent Advances in Plant Disease Management

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India is known as an agricultural country, but the benefits of this progress are mostly confined to rural areas. Most of the population of India are live in rural areas and totally depend upon agricultural produce. Hunger and poverty continue in light of the absence of work openings, in this manner lacking pay for farming communities. Indian agriculture, fundamentally described as methods for subsistence, is changing quickly according to market demands both locally and globally. In current situation, mono-cropping-based escalated agriculture has brought about the loss of biodiversity, flare-ups of pests and diseases, pollution of soil and water, which has at last prompted stagnating agrarian generation and productivity (Bambawale *et al.*, 2008).

Achievement in disease management, as in many different backgrounds, relies upon having the correct instruments and the certainty to apply them. The key apparatus for disease management is learning and having information gives certainty. Diagnostic and warning emotionally supportive networks are confronting enormous difficulties in making significant and viable information and help accessible to farmers and market chains and guaranteeing that upstream specialists are educated regarding the genuine need issues and issues requiring goals. Chemical pesticides have reduced crop losses in several things, however, even with a considerable increase in chemical use, the proportion of crop losses and also the definite quantity of those losses from diseases seem to possess raised over time. Inappropriate and excessive chemical use to increase many times of insect pest outbreaks and extra disease loss attributable to the inadequate destruction of natural enemies of diseases, disease resistance, and comes secondary diseases. Host plant resistance, natural plant products, biopesticides, natural enemies, and science practices supply a probably viable choice for IDM. They are comparatively safe for non-target organisms and humans. Biotechnological tools like marker-assisted selection, biotechnology, and distant hybridization are used to develop resistant crop cultivars it will be better on future disease management programs. Disease modeling, call support systems, and remote sensing would contribute to scaling up and dissemination of IDM methods.

Plant pathology may be a difficult and vital science that deals with the science of disease development and knowledge to manage diseases. Society, consumers, and growers will solely be able to still have the benefit of plant pathology if the discipline can evolve acceptable disease management program which will reply to the many changes in agricultural practices in India; the nal word goal is to supply additional and safer food in total agri-cultural systems that conserve natural resources. Visible of this, a critique on current advances and rising challenges in crop disease management in the Republic of India ought to be viewed as terribly timely and acceptable.

Role of Biotechnological tools in Plant Disease Management

Different approaches in disease management have a great deal been influenced by the recent advances in biological science. Several biotechnological tools and techniques are developed by completely different plant pathogens as experimental materials. The host-pathogen interaction under various environments to convey a completely unique look to the present branch of science paradoxically viewed as 'cut and burn' technology.

Molecular Diagnosis of Plant Diseases

Conventionally, cultural ways are used to isolate and establish potential pathogens. This is often a comparatively slow method, typically requiring skilled taxonomists to dependably establish the bacterial. However, over the last 30 years, many

techniques are developed that have found application in plant-pathogen diagnosis; these embrace the utilization of being antibodies and enzyme-linked immunosorbent assay (ELISA) (Clark and Adams, 1977) and deoxyribonucleic acid-based technologies, like the polymerase chain reaction (PCR), that change regions of the pathogen's order to be amplified by many million fold, therefore increasing the sensitivity of bacterial detection. The deoxyribonucleic acid small array technology, originally designed to review organic phenomenon and generate single nucleotide polymorphism (SNP) profiles is presently a brand new and rising bacterial diagnostic technology and offers a platform for unlimited multiplexing capability (Jalali, 2008). The quick growing databases generated by genetics and systematic analysis give distinctive opportunities for the look of additional versatile, high outturn, sensitive, and specific molecular assays that may address the key limitation of the present technologies and profit plant pathology. Finally, the thus far restricted use of artificial intelligence to deoxyribonucleic acid technology will become economically possible and therefore accessible to farmers and can supply the chance of single DNA chip as sensible tool for the diagnosing of many plant pathogens.

Nanotechnology Role in Plant Disease Management

Nanotechnology offers an essential role in raising the present crop management techniques. Usually, solely a really low concentration of agrochemicals has reached the target website of crops thanks to the activity of chemicals, degradation by photolysis, chemical reaction, and microbe degradation. Hence, repetitive application is required for effective management inflicting unfavorable effects like speedy incidence of resistance and soil and pollution. Nano-formulated agrochemicals ought to be designed in such the simplest way that they hold all necessary properties like effective concentration (with high solubility, stability, and effectiveness), time controlled-release (CR) in response to bound stimuli, improved target activity and fewer eco-toxicity with safe and simple mode of delivery. Therefore, associate pressing would like is to evaluate and develop natural, perishable, and atmosphere safe nano-formulated compounds.

References

Bambawale, O. M., Saradana, H. R., & Arora, S., (2008). Expanding dimensions of plant

protections as per current needs. Crop Care, 34(2), 15–21.

Clark, M. F., & Adams, A. N., (1977). Characteristics of the microplate method of enzyme-linked immunosorbent assay (ELASA) for the detection of plant viruses. J. Gen. Virol., 34, 475–483.

Jalali, B. L., (2008). Molecular plant pathology: Where do we stand. J. Mycol. Plant Pathol., 38(3), 419-429.

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The Impact of Climate Change on Plant Diseases: A Growing Concern

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Climate change has emerged as one of the greatest challenges of our time, affecting various aspects of our environment, including agriculture. As global temperatures rise and weather patterns become more unpredictable, the impact of climate change on plant diseases has become a growing concern. Changes in temperature, precipitation and atmospheric conditions have significant implications for the occurrence, distribution and severity of plant diseases. In this article, we explore the complex relationship between climate change and plant diseases, highlighting the key factors that contribute to their interplay and the potential consequences for global food security.

Changing Climatic Conditions

One of the primary ways climate change influences plant diseases is through altered climatic conditions. Rising temperatures can directly affect the growth and development of both plants and pathogens. Higher temperatures can accelerate the life cycles of many pathogens, leading to increased disease incidence and severity. Similarly, extended periods of warm weather can favor the proliferation and spread of disease-causing organisms, as they thrive in these favorable conditions.

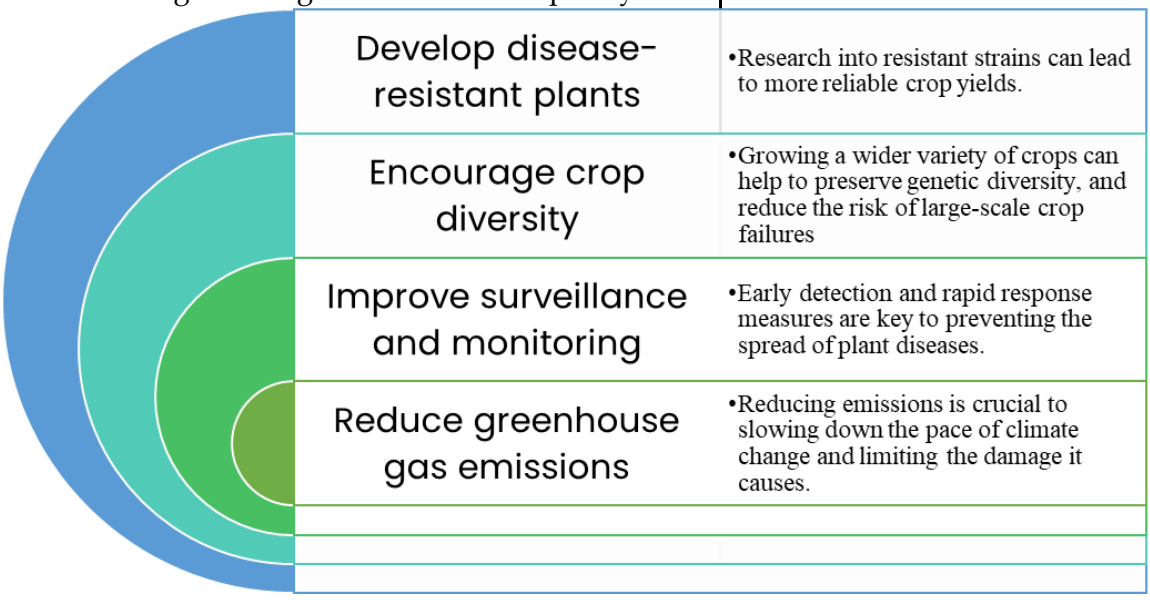
Precipitation patterns are also being disrupted due to climate change. Changes in rainfall frequency and intensity can create a conducive environment for certain plant diseases. Excessive rainfall may lead to waterlogged soils, promoting the growth of pathogens that thrive in wet conditions. Conversely, prolonged drought can weaken plants, making them more susceptible to opportunistic pathogens and reducing their ability to mount effective defenses against diseases.

Altered Distribution of Diseases

Climate change is causing shifts in the geographical distribution of plant diseases. As temperatures warm, regions that were previously inhospitable to certain pathogens become suitable for their survival and growth. This expansion of the pathogen's range can lead to the emergence of diseases in new areas, affecting crops that were previously unaffected. In some cases, diseases that were confined to specific regions may now become more widespread, posing challenges to local agriculture and threatening food production.

Pest and Pathogen Interactions

Climate change not only affects individual pathogens but also disrupts the delicate balance of interactions between pests, pathogens, and their host plants. Changes in temperature and precipitation can influence the abundance and behavior of insect vectors that transmit plant diseases. For instance, warmer temperatures can enhance the reproductive rates of certain insect vectors, leading to increased disease transmission. This complex web of interactions can amplify the impact



of plant diseases and complicate their management strategies.

Significant increases in *Fusarium* spp. diseases of salad crops and powdery mildew (*Blumeria graminis*) on barley have been found under elevated temperatures and CO2. Higher CO2 concentrations can increase fungal disease pressure in wheat and rice, perhaps due to suppressed plant immunity or changes in stomatal and trichome density. In general, while disease responses to elevated temperature and CO2 alone vary depending on the pathosystem in question, interactions between the two drivers are often found to be positive. Most experimental studies have taken current CO2 levels as a baseline (400–450 ppm) to compare with future levels (800–850 ppm). Atmospheric CO2 concentrations have increased from ca. 280 to ca. 415 ppm since the beginning of the industrial revolution, resulting in a mean global temperature increase of 1.1°C. It would therefore be interesting to determine the influence of these historical CO2 changes on plant-pathogen interactions. Changing climate conditions can also impact plant disease management options. For example, the efficacy of mancozeb and azoxystrobin fungicides against Phoma leaf spot (*Phoma betae*) in leaf beet improved significantly under experimental CO2 and temperature increases. Disease control provided by the biocontrol agent *Aspergillus quisqualis* was significantly improved under elevated CO2 and temperature.

Possible Solutions to Mitigate the Impact-Implications for Global Food Security

The consequences of climate change on plant diseases have profound implications for global food security. Crop losses due to diseases can result in reduced yields, compromised quality, and increased production costs. This, in turn, affects the availability and affordability of food, particularly in regions heavily dependent on agriculture for sustenance. Moreover, the changing disease dynamics can disrupt traditional cropping patterns and render certain crops less viable in their current locations, necessitating adaptations and potentially leading to shifts in global food production.

Adapting to the Challenges

Addressing the challenges posed by the impact of climate change on plant diseases requires proactive measures and adaptation strategies. These may include:

1. Developing disease-resistant crop varieties: Breeding and selecting crops with enhanced resistance to diseases can help mitigate the risks posed by changing disease dynamics.
2. Improved disease monitoring and early detection: Enhancing surveillance systems and utilizing advanced technologies for disease monitoring can aid in early detection and prompt response to emerging diseases.
3. Integrated pest and disease management: Employing integrated pest and disease management approaches that combine cultural, biological, and chemical control methods can help minimize the impact of diseases on crops.
4. Enhancing agricultural practices: Implementing sustainable agricultural practices such as crop rotation, diversification, and precision farming can improve plant health and reduce disease susceptibility.
5. International collaboration and knowledge sharing: Strengthening global partnerships, sharing information, and fostering collaborative research can enhance our understanding of the complex relationship between climate change and plant diseases.

Conclusion

The impact of climate change on plant diseases is a multifaceted issue that demands attention. As the global climate continues to evolve, it is imperative that we recognize and address the challenges it poses to agricultural systems. By implementing adaptive strategies and investing in research and innovation, we can mitigate the effects of climate change on plant diseases and work towards ensuring food security for future generations. The time to act is now, for the health of our planet and the sustenance of humanity depends on it.

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Integrated Management of Major Pests of Rice Crop

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Rice (*Oryza sativa) is* one of the most important food crops and feeds nearly 60 % population of India. Although rice protein ranks high in nutritional quality among cereals, protein content is modest, it also provides minerals, vitamins and fiber, although all constituents except carbohydrates are reduced by milling. Therefore, rice being the most consumed cereal grain globally; the growth of rice market is expected to increase. System of intensification is a methodology adopted in various ecosystems and deal with the sustainable best management practices of what farmers have within their available resources which offers the best alternative to increase the productivity of crops with minimum cost. Among the major yield limiting factors pests are said to be an important one. Pest causes 33% production loss in India, the major weed, insect-pests, diseases and other pests causes 12.5, 9.5, 6.5 and 4.5 % respectively. Therefore, to check the yield reduction and quality grain production, the information about identification, damaging symptoms and integrated management of major insect-pests and diseases is given below:

Insect-Pests

Rice Stem Borers: Rice crops are attacked by three species of stem borers, *viz*. yellow, white and pink stem borer from July to October. Yellow (Photo 1) and white stem borer female moths lay eggs near leaf tips in masses, covered with brown anal hairs, whereas pink stem borer (Photo 2) female moth lays eggs singly inside the leaf sheath like beads. The stem borers' larvae bore into stems and feed there. The affected plants in vegetative stage produce yellow and dry central shoots called, '*dead hearts*' (Photo 3). These dead hearts can be easily pulled from the plant, whereas, in older plants, damage symptoms are observed as empty earheads which remain white and stand erect called 'white ears'. Such damaged plants can be easily observed in the field from a distance.

Management: To manage this insect avoid long duration varieties of rice like Pusa 44, Peeli Pusa and Dogar Pusa. Regular monitoring of crop for stem borers damage is necessary. As and when dead heart damage reaches more than 5 % (economic threshold level (ETL)) in rice, apply any one of the insecticide as given in Table 1. Any of these insecticides may be repeated as and when incidence again reaches at ETL. Apply these insecticides alternately.

Leaf Folder: The adults of this insect is yellow to light brown, fore-wings has distinct dark brown wavy lines and dark brown bands along outer margin. The female moth lays translucent, flat and oval eggs singly or in pairs on the underside of leaf blades. After hatching, young larvae feed on green leaf tissues without folding the leaves, whereas older larvae feed on green tissues by folding them. Damaged leaves produce white streaks and become membranous that reduces photosynthetic activities of the crop.

Management: The incidence of leaf folder may be increase under tree shade, due to more egg laying by the insect. So observe the hot spot area of leaf folder infestation cautiously under tree shade to avoid further damage to the crop. To manage this dislodges the larvae pass 20-30 meter long coir/jute rope, forward and backward, both ways while touching the crop canopy. Care should be taken that water must be standing in the crop and this practice should be done before flowering. Regular monitoring of crop for leaf folder damage is necessary. As and when leaf damage reaches at **10 % (ETL)** in crop, apply any of the insecticides (Table 1). Further spray may be given with alternative insecticides as and when leaf damage again reaches at ETH.

Plant Hoppers: Two type of plant hoppers white backed planthopper and brown planthopper attack on rice crop crop. The females lay eggs in leaf sheath tissues. Both nymphs and adults suck sap particularly from the leaf-sheath from July to October. The symptoms of the damage start appearing from leaf tips and spread to the rest of the plant. The crop

severely attacked by planthoppers ultimately dries up in patches. These dried up patches of the crop are called, '**hopper burn**' (Photo 5). As the plants dry up, the hoppers migrate to the adjoining green plants and within a few days, the area of rusty patches enlarges. These hoppers also excrete honeydew as a result of which sooty mould develops on the leaves, which impart smoky hue to the crop and hinder photosynthetic activities.

Management: The incidence of planthoppers can be reduced by following alternate wetting and drying in routine and drain out the water for 3-4 days depending upon the soil type during infestation. Care should be taken that rice/basmati fields do not develop cracks. Regular monitoring of hopper population is necessary. About one month after transplanting, a few plants in the field should be slightly tilted and tapped 2-3 times at the base at weekly interval and count the number of insects falling on the water. After tapping, if a minimum of 5 hoppers per hill (ETL) are seen floating on the water, only then the crop should be sprayed with any of the recommended insecticides (Table 1). Further application of any of the insecticides may be repeated as and when hopper population again reaches at ETL. For better and effective results, direct the spray towards the base of the plants. If damage is noticed at hopper burn stage, treat the affected spots along with their 3-4 meter periphery immediately as these spots harbour high population of the hoppers.

Rice Hispa: The adult beetles of this pest are shiny bluish-black in colour with numerous short spines over the body. So, it is called as kandian waali bhundii. The female beetles lay eggs within the epidermal layers of leaves, usually on underside of the apical portion of leaves. After hatching the grubs' tunnel into the leaves, whereas, the adults are external feeders. The grub causes damage by producing bold, white streaks on the leaves.

Management: If attack of this insect starts in the nursery, clip-off and destroy the leaf tips at the time of transplanting. If damage noticed in transplanted crop, spray the crop with any of insecticides (Table 1).

Diseases

Sheath Blight (*Rhizoctonia solani*): It is very serious fungal disease of rice crop. The fungal *sclerotia* (a compact mass of hyphae) survive throughout the year in soil and plant debris. Plants are more vulnerable to sheath blight during the rainy season. It occurs in areas where the temperature 28−32°C, relative humidity of crop canopy from 85−100% and use of excessive nitrogen fertilizer. The symptoms of diseases appear on the plants like grayish green lesions with purple margin develop on the leaf-sheath above the water level. Later, the lesions enlarge and coalesce with other lesions. In severe attack of disease resulted that poor filling of the grains.

Management: Destroy the paddy straw and stubbles after harvesting the affected crop. Use of balanced nitrogenous fertilizers dose. Regular survey of the crop is necessary when disease appear in the crop then make the spray of 150 ml Pulsor 24 SC (thifluzamide) or 26.8 g Epic 75 WG (hexaconazole) or 400 ml Galileo Way 18.76 SC (picoxystrobin + propiconazole) or 200 ml Amistar Top 325 SC or Pikapika 25 EC (propiconazole) or 320 ml Lusture 37.5 SE (flusilazole + carbendazim) in 200 litres of water per acre.

Blast (*Pyricularia grisea*): It is attack on above ground parts of the plants, leaves, nodes and neck. The fungal organisms survive overwinter in the infected seeds and stubbles. The initial symptoms appear on plants like spindle shaped spots with greyish centre and brown margin on the leaves at maximum tillering. It also causes brown lesions on the neck of the panicle, showing neck rot symptoms and the panicles fall over. The disease severely effects on basmati crop particularly in the sub-montaneous regions. The excessive application of nitrogenous fertilizers increases the incidence of disease.

Management: After appearance of disease symptoms spray the crop with 200 ml Amistar Top 325 SC (azoxystrobin + difenoconazole) or 500 g Indofil Z-78, 75 WP (zineb) per acre in 200 litres of water, at the boot and ear-emergence stages.

False smut (*Ustilaginoidea virens*): It is one of the emerging fungal grain disease of rice, wherein the

individual rice grains get transformed into large yellowish/greenish velvety spore-balls (Smut balls). The smut balls are initially yellow in colour and later on its burst and the colour changes to orange, yellowish green, green, olive green and finally greenish black. Only few grains in a panicle are usually infected and rest of grains become normal. Favorable weather like high relative humidity, rainy and cloudy days during the flowering period increase the incidence of the disease. The application of organic manures and high dose of nitrogenous fertilizers also increases the intensity of attack.

Management: To manage this disease, spray the fungicides 400 ml Galileo Way 18.76 SC (picoxystrobin + propiconazole) or 500 g Kocide 46 DF (copper hydroxide) in 200 litres of water per acre at boot stage of the crop in disease prone areas.

Brown spot of rice (*Drechslera oryzae*): This is well known fungal disease of rice caused by *Helminthosporium oryzae* (Syn. *Bipolaris oryzae, Drechslera oryzae*). The disease appears from seedling to milking stage. The symptoms of the disease start on leaves as oval, eye-shaped spots with a conspicuous dark-brown dot in the centre and light brown margin. Spots are also produced on the grains. The relative humidity (86−100%) and temperature between 16 and 36°C are the favorable weather of disease development. It disease commonly appear in nutrient-deficient soil, or in soils that accumulate toxic substances.

Management: Apply fertilizers on soil testing or leaf colour chart base. Spray the crop with 80 g Nativo 75 WG (trifloxystrobin + tebuconazole) in 200 litres of water/ac at disease initiation. First spray at boot stage of crop and repeat the second spray 15 days interval.

Bunt/Kernel Smut (*Neovossia horrida***):** Due to this disease the only few grains are infected in the panicle. Frequently, only a part of the grain is replaced by a black powder. Sometimes, entire grain is also attacked and the black powder scatters on to other grains or leaves, and this is often the easiest way to detect the disease in the field. Avoid heavy doses of nitrogenous fertilizers.

Note: To spray insecticides by using 100 litres of water per acre with Knapsack sprayer having fixed type hollow cone nozzle

Conclusion

Insect-pests and diseases of rice crop can be successfully managed by integrating different control methods. This will be more helpful to the rice growers and shelling industry for getting higher economic returns. Farmers should remain vigilant right from the transplanting the crop till harvesting. All the affected plant parts along with eggs/insect larvae/disease spores/infected plant parts should be removed and destroyed. There are many species of natural enemies in rice ecosystem (spiders, coccinellids, dragon fly, damsel fly and *Trichogramma*) those are very effective in against insect-pests. So, the farmers are suggested to apply need based insecticides and fungicide only.

Caution

- Do not give early season blanket application of pesticides, particularly synthetic pyrethroids as they result in an increase in the population of harmful insect-pests and **kill the natural enemies and d**o not repeat the same pesticide after its first spray.
- Apply only recommended dose of insecticides/fungicides and these should not be increased or decreased.

Table 1. Recommended insecticides against insect-pests

Insect/ Crop	Insecticide	Brand(s)	Dose/ac	Method of application
Stem borers	chlorantraniliprole*	Coragen 18.5 SC	60 ml	Spray
	flubendiamide 39.35%*	Fame 480 SC	20 ml	
	flubendiamide 20%*	Takumi 20WG	50 g	
	cartap hydrochloride	Mortar 75 SG	170 g	
	chlorpyriphos	Coroban/Dursban/Lethal/Chlorguard/ Durmet/Classic/ Force 20 EC	1 litre	
	azadirachtin 5%	Ecotin	80 ml	
Leaf folder	chlorantraniliprole*	Coragen 18.5 SC	60 ml	Spray
	flubendiamide 39.35%*	Fame 480 SC	20 ml	
	flubendiamide 20%*	Takumi 20WG	50 g	
	cartap hydrochloride	Mortar 75 SG	170 g	
	chlorpyriphos	Coroban/Durmet/Force 20 EC	1 litre	
	azadirachtin 5%	Ecotin	80 ml	
Plant hoppers	triflumezopyrim	Pexalon 10 SC	94 ml	Spray
	dinotefuran	Osheen/ Token 20 SG	80 g	
	pymetrozine	Chess 50 WG	120 g	
	Quinalphos	Ekalux/Quinguard/Quinalmass 25EC	800 ml	
	azadirachtin 5%	Ecotin	80 ml	
	PAU Homemade Neem Extract	PAU Homemade Neem Extract	4 litre	
Rice hispa	quinalphos	Ekalux 25 EC	800 ml	Spray
	chlorpyriphos	Dursban 20 EC	1 litre	

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Biological Control of Plant Pathogens: An Eco-Friendly Disease Management

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Due to the continuous use of pesticides and fungicides in large quantities to manage the plant diseases has seriously raised a concern about the contamination of the ecosystem because of the introduction of these potent dangerous chemicals in to the agriculture system over years. The existence of the chemicals in the ground leads to the contamination of air, water and degradation of land as these particles takes more time to degrade in the natural system. So, there is an high need of alternative management of plant diseases (Collinge *et al.,* 2022). An eco-friendly and sustainable alternative to chemical-based remedies for managing plant infections and pests is biological control.

Biological control

The use of living organisms to govern or restrict populations of plant pathogens, pests or invasive species is known as biological control, sometimes known as biocontrol. Beneficial insects, parasitoids, predatory nematodes, microorganisms such as bacteria and fungi and even other plants are examples of these organisms. The organisms which are used in the biocontrol management are called as biocontrol agents (BCA). Unlike chemical pesticides, biological control approaches rely on natural enemies of plant pathogens to maintain ecological equilibrium (Fira *et al.,* 2018).

Need for eco-friendly plant pathogen management

As stresses about the environmental impact of chemical pesticides mount, there is an compelling necessity to move to more sustainable and environmentally friendly agricultural practices. Non-target creatures can be harmed by chemical pesticides, which can contaminate soil and water and lead to the development of pesticide-resistant pathogens. Biological control tackles these concerns by providing a comprehensive and environmentally benign method that minimises ecosystem damage and supports long-term pathogen management.

Beneficial biocontrol agents

Microorganisms are critical components of biological control techniques that aim to manage plant diseases while minimising environmental effect. In this section, we will look at the importance of harnessing the power of helpful microbes and the different varieties used in plant pathogen control.

Harnessing the power of microbes

Microbes are widely recognised as having the potential to inhibit plant diseases. These microscopic creatures have the ability to colonise plant surfaces and interact with diseases, either directly antagonising them or boosting the plant's innate defence mechanisms. Utilising the potential of helpful microorganisms is a key component of environmentally responsible plant disease treatment.

Beneficial microorganisms utilized in plant pathogen control

To tackle plant infections, a varied array of helpful microbes has been mobilised in the search for sustainable agriculture. In this section, we will look at different types of microorganisms, each with their distinct way of action:

Antagonistic bacteria: Bacterial strains that produce antimicrobial chemicals and compete for resources with harmful microbes, limiting their growth are known as antagonistic bacteria.

Ex: *Bacillus* bacteria have inhibited soybean seed pathogenic fungi *in vitro*, *Rhizoctonia solani*, *Sclerotinia sclerotiorum* and *Phomopsis* sp (Widnyana and Javandira, 2016).

Pseudomonas fluorescens acts against *Fusarium* wilt and *Rhizoctonia* damping off in tomato and pepper (Domenech *et al.,* 2006).

Fungal Antagonist: Mycoparasitic fungi such as *Trichoderma* and *Ampelomyces* parasitize pathogenic fungi, interrupting their development and decreasing illness severity.

Ex: *Trichoderma asperellum* and *Metarhizium anisopliae* are used to control powdery mildew (*Leveillula taurica*)in pepper (Lopez *et al.*, 2019).

Endophytes: Endophytes are microorganisms that reside within plant tissues and can help the plant resist infections by secreting protective chemicals or generating systemic immune responses.

Beneficial Rhizobacteria: Rhizobacteria, such as nitrogen-fixing bacteria, can benefit plant health by improving nutrient uptake and in turn, indirectly reducing pathogen pressure.

Biopesticides

Biopesticides are gaining popularity as safe and sustainable pest and disease management solutions in agriculture. Biopesticides are natural disease management products derived from microorganisms, plants, animals and their byproducts. They are designed to control pests like insects, weeds and plant pathogens while minimizing harm to non-target organisms and the environment (Koul, 2023). Biopesticides are considered an eco-friendly and sustainable alternative to synthetic chemical pesticides because of their lower toxicity and fewer negative ecological impacts.

There are three types of biopesticides namely microbial biopesticides, plant-incorporated protectants (PIPs) and biochemical biopesticides (Fragkouli *et al.*, 2023). Microbial biopesticides contain living microorganisms that can infect or parasitize pests, such as *Bacillus thuringiensis* (Bt) and *Metarhizium anisopliae*. Plant-Incorporated Protectants (PIPs) are genetically modified crops that express proteins derived from naturally occurring microorganisms, such as Bt crops. Biochemical biopesticides are naturally occurring substances extracted from plants, animals or microorganisms, disrupting the physiology or behaviour of pests.

Biopesticides have many advantages, including being environmentally friendly, having reduced chemical residues, targeting specific pests and being less toxic to humans and animals. They are also a key component of integrated diseases management, promoting sustainable and holistic approaches to disease control. However, biopesticides face challenges such as limited persistence, specificity, regulatory hurdles and cost.

Biopesticides are utilized in various agricultural settings, including organic farming, conventional agriculture and integrated pest management programs, to manage a broad range of pests, including insects, weeds and plant diseases. As research and development in this field continue, biopesticides are expected to play an increasingly significant role in modern agriculture.

Safe and sustainable disease management

Biopesticides represent a significant departure from traditional chemical pesticides, providing a safer and more ecologically friendly approach to pest and pathogen management. Biopesticides, unlike their chemical equivalents, are obtained from natural sources such as beneficial bacteria, plant extracts or biochemicals. Because of this differentiation, they are less harmful to humans, non-target creatures and the environment.

The emphasis on safety and sustainability in biopesticide use is consistent with rising understanding of the negative impacts of chemical pesticides on ecosystems, beneficial organisms and the development of fungicide-resistant pathogens. Biopesticides not only alleviate these problems, but also contribute to agricultural ecosystems long-term health and resilience.

Development and use of biopesticides

Creating efficient biopesticides necessitates substantial study and development. This section will go over the various stages of biopesticide development, such as:

Isolation and screening: Identifying and isolating pest-controlling microbes or chemicals from nature.

Formulation: Creating formulations that improve the stability and effectiveness of biopesticides for use in the field.

Field Trials: Extensive testing in real-world agricultural settings to determine the efficacy and safety of biopesticides.

Regulation and Registration: Navigating regulatory processes to guarantee biopesticides meet commercial safety and efficacy standards.

Integrated Disease Management (IDM): The use of bioagents into comprehensive IDM programmes that combine multiple pathogen control approaches for maximum performance (Rong *et al.*, 2020).

Advantages of biological control

1. Reduced Chemical Dependency: It minimizes the need for synthetic chemical pesticides, reducing the chemical residues in the environment and preventing the development of pesticide-resistant pathogens.
2. Soil and Water Protection: By reducing chemical runoff and soil contamination, it helps to safeguard water quality and preserve soil fertility.
3. Reduced Resistance Development: Unlike chemical pesticides, biocontrol methods are less prone to the development of resistance in pathogens and pests.
4. Enhanced Precision: The specificity of biocontrol allows for precise pest and disease management, reducing the risk of overuse or unintended harm to beneficial species.
5. Lower Carbon Footprint: It typically has a lower environmental footprint compared to the production and application of synthetic chemicals.
6. Organic farming compatibility and certification: Biological control methods are compatible with organic farming practices and are widely accepted in organic certification standards.

Limitations of biological control

1. Specificity: Many biocontrol agents are highly specific to particular pathogens or pests. This means that they may not be effective against a wide range of pathogens.
2. Effectiveness: The effectiveness of biocontrol can vary depending on environmental conditions, such as temperature, humidity and soil type.
3. Slow Action: Biocontrol agents often take longer to show results compared to chemical pesticides.
4. Incompatibility with Certain Practices: Some agricultural practices, such as the use of certain chemical pesticides or soil fumigation, can harm or disrupt biocontrol agents, limiting their effectiveness.
5. Cost: While biocontrol can lead to long-term cost savings, the initial investment in research, development and implementation can be higher than conventional chemical pest management.
6. Knowledge and Training: Successful use of biocontrol often requires specialized knowledge and training. Farmers need to understand the life cycles and interactions of biological control agents and their target pathogens.
7. Availability: Availability of specific biocontrol agents can be limited in certain regions, making it difficult for farmers to access and implement these methods.

Conclusion

Biological control of plant diseases is a ray of hope in the field of environmentally friendly disease management in agriculture. This sustainable strategy has several positive aspects ranging from environmental stewardship and human safety to long-term efficacy and tailored disease management. We may reduce the ecological harm associated with chemical pesticides while improving the health and resilience of our agricultural ecosystems by utilising the power of beneficial bacteria, predatory insects, and natural antagonists. Yet it is crucial to realise the inherent constraints and difficulties that come with biological control, including regulatory barriers and issues with specificity and efficacy. Even if it is not a magic solution, it is a crucial part of Integrated Disease Management techniques that encourage peaceful cohabitation between agriculture and the

environment. In our drive for sustainable, wholesome and resilient crop systems, biological management is poised to become more and more important as research continues to reveal new technologies.

References

Collinge, D.B., Jensen, D.F., Rabiey, M., Sarrocco, S., Shaw, M.W. and Shaw, R.H. (2022). Biological control of plant diseases–What has been achieved and what is the direction?, Plant Pathology, 71(5), 1024-1047.

Fira, D., Dimkic, I., Beric, T., Lozo, J. and Stankovic, S. (2018). Biological control of plant pathogens by *Bacillus* species. Journal of biotechnology, 285, 44-55.

Koul, O. (2023). Biopesticides: commercial opportunities and challenges. Development and Commercialization of Biopesticides, 1-23.

Fragkouli, R., Antonopoulou, M., Asimakis, E., Spyrou, A., Kosma, C., Zotos, A., Tsiamis, G., Patakas, A. and Triantafyllidis, V. (2023). Mediterranean Plants as Potential Source of Biopesticides: An Overview of Current Research and Future Trends. Metabolites, 13(9), 967.

Rong, S., Xu, H., Li, L., Chen, R., Gao, X. and Xu, Z. (2020). Antifungal activity of endophytic *Bacillus safensis* B21 and its potential application as a biopesticide to control rice blast. Pesticide Biochemistry and Physiology, 162, 69-77.

Widnyana, I.K. and Javandira, C. (2016). Activities *Pseudomonas* spp. and *Bacillus* sp. to stimulate germination and seedling growth of tomato plants. Agriculture and Agricultural Science Procedia, 9, 419-423.

Domenech, J., Reddy, M.S., Kloepper, J.W., Ramos, B. and Gutierrez-Manero, J. (2006). Combined application of the biological product LS213 with *Bacillus*, *Pseudomonas* or *Chryseobacterium* for growth promotion and biological control of soil-borne diseases in pepper and tomato. BioControl, 51, 245-258.

Lopez, C.G., Castellanos, L.N.M., Ortiz, N.A.F. and Gonzalez, J.A.G. (2019). Control of powdery mildew (*Leveillula taurica*) using *Trichoderma asperellum* and *Metarhizium anisopliae* in different pepper types. BioControl, 64(1), 77-89.

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Role of Artificial Intelligence in Plant Protection

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The United Nations Food and Agriculture Organization (FAO) reported that the burgeoning global population will be around two billion by 2050, while only 4% additional land will come under cultivation by then. It's an uphill task for the farming community to feed the ever-increasing world population amid rising agricultural debts, unpredictable weather patterns and biotic stress.

Insect pests and diseases are one of the major reasons for decreasing farm productivity causing 20 to 40 percent global crop loss every year. In the absence of knowledge and expertise, farmers are over-dependent on pesticide dealers for support on pest identification and their management, which results in excessive and injudicious use of pesticides for controlling the pests. The major concern of farmers for decision making in pest management is "pest identification and timely availability of correct pest management information". To detect plant pests at an early stage and save undesirable consumption of pesticides, advanced technical solutions are needed in agriculture which will result in saving crop worth crores of rupees or in non-application of intervention saving the cost of intervention involved and thus saving the environment. The core of the pest management framework is the decision-making process. Decision-making in pest management is a dynamic and complex process that requires much more knowledge and support than conventional agriculture.

Pest identification and availability of correct management information are the vital aspects of process of decision-making in pest management. Eye/physical observation methods have been used in recent years, but they are not efficient. The future of farming depends largely on adoption of cognitive solutions. Hence Artificial Intelligence (AI) plays a major role which can greatly help in efficient and successful crop pest management.

Role of Artificial Intelligence in pest management

Plant protection is an extremely important aspect of agriculture to boost crop production and thereby food security. The plant protection measures are to be taken on a community basis so as to ensure effective management of pests and hence Artificial Intelligence (AI) techniques has been recently introduced for precision control of plant insect pests. There are different ways of AI in pest management, which are described as follows.

Easy method for scouting fields: AI can help the scouts in providing accurate descriptions of pest and their exact location in fields.

Addressing challenges in diagnosis of pest: Proper identification of specific pest in the field is important for its successful management. Another important aspect of pest management is regular pest monitoring, which helps to determine the level of incidence and timing to initiate pest management intervention.

Predicting pest problems early: Application of AI techniques can help to automate and speed up the process of providing timely and correct decision-support to the farmers on important aspects of pest management such as pest identification, pest monitoring and selection of appropriate pest management strategy

Large-scale pest monitoring and surveillance: Drones which work on principles of artificial intelligence are used for **pest monitoring, surveillance.**

Pest management: Spraying of pesticides by AI based drones to control pest efficiently over a larger area by ensuring complete coverage of crop.

Benefits of Utilizing AI Methods in Crop Protection

The integration of robotics and artificial intelligence (AI) into agriculture has revolutionized the way crops are grown and protected. While the title "Sustainable Crop Protection via Robotics and

Artificial Intelligence Solutions" suggests a focus on pest control, it is crucial to recognize that AI and robotics can contribute to comprehensive crop protection strategies. By leveraging these technologies, we can enhance agricultural practices and ensure a sustainable future for food production. While our primary focus lies in crop protection, specifically in the realms of weed and disease management, it is essential to acknowledge the broader scope of whole crop protection and monitoring. In this section, we aim to provide a concise overview of these additional components and highlight the invaluable contribution of AI solutions to these areas.

Crop protection encompasses various factors beyond weeds and diseases that significantly impact crop health and yield. Elements such as climate conditions, nutrition optimization, cultural activities, and plant physiology play crucial roles in ensuring comprehensive crop protection strategies. By leveraging AI solutions, we can unlock new possibilities and advancements in each of these areas.

Climate adaptation and resilience: Climate change poses significant challenges to agricultural productivity. AI and robotics can play pivotal roles in adapting and mitigating climate-related risks. Advanced algorithms can process vast amounts of climatic data, helping farmers make informed decisions about planting times, water usage, and crop selection. Robotics equipped with environmental sensors can monitor weather conditions, soil moisture levels, and pest outbreaks, providing real-time data to optimize crop management. With AI-driven climate modeling, farmers can anticipate weather patterns, allowing for timely adjustments and minimizing crop losses.

Nutrition optimization: Achieving optimal crop nutrition is crucial for both yield and quality. AI and robotics can optimize nutrient management by analyzing soil composition, plant nutrient requirements, and growth patterns. Intelligent systems can monitor nutrient deficiencies or excesses, enabling precise application of fertilizers or other supplements. Additionally, robotics can automate tasks such as precision seeding, weeding, and nutrient delivery, minimizing waste and maximizing resource efficiency. By tailoring nutrition strategies to specific crop needs, AI and robotics contribute to sustainable agriculture while reducing environmental impacts.

Cultural Activities and Labor Optimization: Agriculture encompasses a range of cultural activities that are essential for successful crop production. AI and robotics can automate and streamline various tasks, reducing labor-intensive efforts and optimizing resource allocation. For example, robotic systems can perform time-consuming activities such as harvesting, pruning, and sorting with greater accuracy and efficiency. By automating repetitive tasks, farmers can focus on higher-value activities, such as crop planning, disease management, and market analysis. The integration of AI and robotics not only enhances productivity but also improves the quality of life for farmers, making agriculture a more attractive profession.

Enhancing plant physiology and health: Understanding plant physiology is vital for effective crop protection. AI can analyze large datasets on plant physiology, growth patterns, and disease symptoms, enabling early detection and intervention. By analyzing the relationships between plant traits and environmental conditions, AI can develop models to predict plant stress and disease susceptibility. Robots equipped with cameras and sensors can precisely monitor plant health, detecting signs of nutrient deficiencies, water stress, or pest damage. This data-driven approach allows for proactive management strategies, reducing the reliance on reactive measures and promoting sustainable plant health.

References

Khan, N.; Ray, R.L.; Sargani, G.R.; Ihtisham, M.; Khayyam, M.; Ismail, S. Current progress and future prospects of agriculture technology: Gateway to sustainable agriculture. *Sustainability* 2021, *13*, 4883.

Mesías-Ruiz, G.A.; Pérez-Ortiz, M.; Dorado, J.; de Castro, A.I.; Peña, J.M. Boosting precision crop protection towards Agriculture 5.0 via

machine learning and emerging technologies: A contextual review. *Front. Plant Sci.* 2023, *14*, 1143326.

Rempelos, L.; Barański, M.; Sufar, E.K.; Gilroy, J.; Shotton, P.; Leifert, H.; Średnicka-Tober, D.; Hasanaliyeva, G.; Rosa, E.A.; Hajslova, J.; et al. Effect of climatic conditions, and agronomic practices used in organic and conventional crop production on yield and nutritional composition parameters in potato, cabbage, lettuce and onion; results from the long-term NFSC-trials. *Agronomy* 2023, *13*, 1225.

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Pokkah Boeng Diseases a Threat to Sugarcane

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Chalorotic Phase

Top rot Phase

Knife cut Phase

Sugarcane (*Saccharum officinarum* L.) is important well known cash crops because it improves socio-economic standard of many sugarcane farmers. The production of sugarcane is mostly focused in tropical areas, especially in developing countries in Latin America, Africa, and Asia, primarily India, where the annual production is close to 1.80 billion tones. In India, sugarcane ranks third after paddy and wheat. It is grown in the tropical and subtropical regions of India on an area of 5.11 million ha with a production of 400.22 million t and a productivity of 78.30 t/ha. Four major states, namely Bihar, Haryana, Punjab and Uttar Pradesh in the subtropical regions, have 2.64 million ha of sugarcane area with a production of 206.72 million t and productivity of 73.68 t/ha, while seven major states, namely Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Madhya Pradesh and Orissa in the tropical regions, have 2.23 million ha of sugarcane area with production of 178.12 million tones and productivity of 76.30 t/ha.

The differences in state wise cane production, productivity and sugar recovery is being reported because of the varietal scenarios and their susceptibility to biotic and abiotic stresses specially the incidence of diseases and insect pests. Among the incidence of diseases, pokkah boeng is the re-emerging most widely spreading serious threat to sugarcane cultivation. It is caused by the pathogen FSC (*Fusarium* species complex). However, it is specified with *Fusarium moniliformae* and was first described by Sheldon. The perfect stage of pathogen is *Gibberella fujikuroi* (Sawada). Pokkah boeng, the term of Javanese denotes the malformed top. Initially, it's incidence was reported by Padwick with no causal agent. Pokkah boeng has now become the devastating disease not only in Punjab but also in whole North West zone of India. This disease is well-known since long time but severity of disease incidence in India is being reported since last half decades (2017-18) with wide spread cultivation of Co 0238 in North India and of Co 86032 and Co C671 in South India. This disease reduces the juice quality and cane tonnage of the harvested crop mainly depending upon the kind of variety.

Symptomatology: The initial symptoms of the disease, which is caused by pathogen FSC (*Fusarium* species complex) appear on young leaves during the monsoon season. Many stages of the symptoms have been observed during the disease progression.

Chlorotic Phase: The first sign of pokkah boeng disease is appear as a green condition at the base of young leaves, which rarely occurs on other parts of the leaves. It is often observed that the underside of the affected leaf is narrower than the underside of a normal leaf. The ladder-shaped lesion on the spindle-shaped leaves is obviously yellow, the spindle is wrinkled, twisted or tangled, red streaks appear, the leaves become shorter and the young leaves are deformed. When the leaves mature, irregular reddish streaks and spots appear in the area of chlorosis.

Top-Rot Phase: The pokkah boeng top rot stage is an advanced and severe stage. Sometimes the

infection from the leaf extends downward and enters the stem at the growth point. The spindle blades were clearly wrinkled, twisted, rotten in the late stages of infection and the entire root of the spindle and even the growing point had leaf abnormalities. Also visible were crimson streaks and dots. Decay will start to show up when the condition is advanced. The plants perish as a result of killing the growth points.

Knife-Cut Phase: The symptoms of the knife-cut stage occurred in association with the acute phase of the disease. The knife-cut stage is characterized by one, two, or even more transverse cuts in the bark of the stem or petiole that are so uniform that it appears as if the tissue has been cut with a sharp knife. This is a typical stage of pokkah boeng disease. Usually, the infection occurs uniformly at the top of the cane, which is obviously the cause of the spread of the disease. Rachis infection sometimes continues to the stem, and dark red streaks may be noted extending over several internodes. When the leaves are pulled off, a large horizontal cut appears on the stem. As the name implies, the most obvious function of pokkah boeng is to deform the top of the sugarcane. However, the infection can also spread to the stem where internal and external ladder-like (knife cut) lesions can occur. The most serious damage occurs when the fungus infects the shoot tip, which may die and rot. Infection occurs when spores are propelled from the air between partially unfurled leaves to the roots of the spindle during rapid growth under warm conditions, and by rain. Then the spores germinate and infect the young tissue of the spindle.

Predisposition Factors

The dispersal of pathogen is significantly influenced by the temperature, it develops and sporulates under both in vitro and in vivo conditions in the range of 20-30°C. A temperature of 30°C is suitable for the pathogen to flourish. The disease is most severe when temperatures are between 20°C and 32°C, humidity is 70-80%, and the weather is cloudy during the rainy season from July to September. Temperatures between 20 and 30°C and humidity between 75 and 85% are the best conditions for the growth of this complex Fusarium pathogen. The pathogen survives for a maximum of 11 months under natural conditions in a soil depth of 30 cm. Cool and dry weather conditions favour the survival of the pathogen in plant debris for a long period of time.

Management strategy: Important tips should be followed by the farmers to manage the disease:

1. Use healthy seed material for planting/plant resistant varieties.

2. Integrated Disease Management practices are the best way to prevent the incidence of disease. Canes showing 'top rot' or 'knife cut' should be rouged out from the fields.

Conclusion

The Pokkah boeng disease poses a significant threat to the global sugarcane industry due to its destructive nature and wide prevalence. It causes substantial economic losses by reducing yields and affecting the quality of sugarcane. Effective management of pokkah boeng requires a widespread approach that integrates various strategies, including the use of resistant varieties, sanitation measures, and chemical control methods. By implementing the tips like integrated management practices and adopting preventive measures, sugarcane farmers can minimize the impact of pokkha boeng and safeguard their crops. Collaboration between scientists, farmers, and agricultural organizations is crucial to combat this disease effectively and ensure the long-term sustainability of the sugarcane industry.

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False Smut Disease: Importance, Distribution, Ecology and Epidemiology

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Rice crop is known to be attacked by many pests and diseases which cause huge losses annually because of more intensive cultivation and high usage of nitrogenous fertilizers and less availability of resistant varieties. Among diseases of rice, fungal disease cause huge economical yield loss and among fungal diseases rice, false smut caused by *Ustilaginoidea virens* (Cooke) Tak is of significant economic importance in recent years.

Rice false smut, also known as green smut, pseudo smut has been recorded in all rice growing countries worldwide. Earlier it was regarded as a minor disease, occurring sporadically in certain regions, but now epidemics of the disease is being reported in different rice growing regions of the world like Japan, Malaysia and some parts of India like Tamil Nadu. It is an important devastating disease causing yield losses from 1.01 to 10.91% (Atia, 2004). Disease incidence of 10-20% and 5-85% respectively has been reported from Punjab and Tamil Nadu on different rice cultivars (Ladhalakshmi *et al*., 2012). The disease has been reported to cause yield loss up to 17.12 in Karnataka (Muniraju *et al*., 2017a; sharanabasav *et al*., 2021; Huded *et al*., 2022). In recent years, its outbreak might be due to high input cultivation, increased use of hybrid varieties, and climate change.

Economic importance

Rice false smut, also known as green smut, pseudo smut has been recorded in all rice growing countries worldwide. False smut causes chalkiness of grains which leads to reduction in grain weight. It also reduces seed germination. The damages by false smut disease include the reduction in economic yield, contamination of grains and straws with ustiloxins, production of mycotoxins and the formation of antimitotic cyclic peptides in chlamydospores (Interfere and affect on cell division) and these chlamydospores, sclerotia and its mycotoxins which are very poisonous to both human and animals and cause different ill effects on human health on consumption of false smut infected grains, so false smut is having its unique importance.

Extent of damage of the disease

Number of smut balls reached as many as 135 (recorded in one panicle in 2015), In the natural observation 34.4, 53.9 and 11.7% of the smut balls were located at the base, mid and apex part of the infected panicles, respectively. Rice false smut (rfsm) is recognized worldwide as an emerging fungal disease and predominant during Aman (late monsoonal rice) season. Hindering adoption of promising rice varieties, such as BRRI dhan 49. Singh and Dube (1978) reported 44 per cent loss in Ratna and 17 percent in IR 8. Yield loss from rfsm has been reported in the range of below 1 to over 75. Mean disease severity was ranged from 4.44 to 17.12 % from Karnataka (Muniraju *et al*., 2017a). Important problem in the punjab state and widespread in commercial cultivar PR 116. Yield loss due to false smut were reported in many countries such as, Columbia (20 %) in the year of 1952; Peru (25 %), Bangladesh in (50.3 to 75.4) in 1986, china (633,000 ha ; 1.37 billion tonns of yield) (2005); Sichuan china (2005) (75^; 330,000 ha; 20-40*); Northern japan (1998) (Severe incidence); Nigeria (58.3) in (2002); USA (1-15^); Egypt (1.01 to 10.91) (2004); Fizi (10) (1956). Disease within Indian states is varied significantly such as., Uttar Pradesh (0.2 - 44.4); Madhya Pradesh (.6 – 75.4); Orissa (15-20); Punjab (70); Andaman & Nicobar Islands (0.04 -49); Haryana (28.5); Gujarath (10-18); Kashmir (45.7); Maharastra (72); Tamilnadu (5-85); Chhatisgarh (16.8-40.7) and Udupi, Karnataka (23) (Dangi *et al*., 2020).

Symptoms of the disease

False smut disease in rice, belongs to Ascomycetes producing symptoms on rice panicle, can be seen after the panicle open and pathogen infection transforms individual grain into initially orange, green later velvety, finally black smut balls on

panicles and cause economic damage and at the crop maturity stage.

Figure 1. Symptoms at different stage of the disease

Figure 2. Culture and chlamydospore production on the XBZ solid mediu media

The Pathogen

Pathogen has been identified in both sexual and asexual stages. Pathogen belongs to the phylum ascomycota and different taxonomic position is given below.

Table 4. Scientific classification of pathogen

Kingdom	Telemorph	Anamorphic
Phylum:	Ascomycota	Ascomycota
Class:	Ascomycetes	Ascomycetes
Sub class:	Sordariomycetes	Incertaesedis
Order:	Hypocreales	Incertaesedis
Family:	Claviceptaceae	Incertaesedis
Genus:	*Villosiliclova*	*Ustiloginoidea*
Species:	*virens*	*virens*

False smut spore balls or sclerotia (sclerotia = pseudomorph) (Figures 1.1 and 1.2) are found growing in association with *Oryza sativa*, on *Zea mays* L. and a few other tropical Graminae hosts that have no significant economic importance. Spore balls are comprised of a proliferation of branched, radial and compacted hyphae that give rise to spherical to elliptical (3-5 X 4-6 µm), warty olivaceous chlamydospores at the terminus. The chlamydospores are smooth, round to elliptical when immature but warty, spiny and yellow to orange pigmented when mature. The chlamydospores become olivaceous, globose to irregularly round, as they mature and the surface is ornamented with prominent spines. In culture, the chlamydospores germinate and produce fine germ tubes that give rise to 1- 3 small ovoid secondary conidia. *U virens* can be cultured on potato dextrose agar (PDA) or potato dextrose sucrose agar (PDSA), but the fungus is slow growing and has two different colony types. The two colony types are either green, hardened sclerotia-like after incubation for two weeks or white, spreading mycelia after incubation for three weeks (Figure 1.3). Further, the fungus can also be grown in liquid broth. Descriptions of the teleomorphic stage, *Villosiclava virens*, include flat, botuliform, reniform, horseshoe-shaped or differently shaped, 1 to several, usually 2, protruding from sclerotia (or pseudosclerotia) overwintering in the field and producing a stalked stromata (=4 ascomata) containing perithecia with about 300 asci in the summer or fall of the following season. The asci are described as cylindrical, hyaline, filiform, unicellular, 120-180 X 4 µm (130-300 X 4-7 µm) and contain eight ascospores that are hyaline, filiform, septate disarticulating at septa to form four part-spores 120-180 X 0.5-1 µm (140-230 X 1.3-1.8 µm) (Tanaka *et al*., 2008). The four part-spores are aseptate and are 30-60 µm.

Sharanabasav *et al*., 2021 characterized the sixty one geo-distinct isolates of *Ustilaginoidea virens* for morpho-molecular and mating-type locus diversity. *MAT1* loci analysis indicated the distribution of heterothallic mating types in south Indian paddy fields. This is the first report describing the sexuality of Indian strains of the *U. virens*, which would help better understand the genetic diversity of the *U. virens* prevailing in Southern India.

Isolation of *U. virens*

The collected smut balls were surface sterilized by dipping them in 70% ethanol followed by 0.1% mercuric chloride and subsequently washed with sterile distilled water. Using a sterilized inoculation loop, the mass of chlamydospores were streaked onto Petri dishes containing potato sucrose agar medium (PSA) under aseptic condition. To avoid bacterial

contamination, Streptomycin at 100 ppm per litre was added in the medium at lukewarm stage before pouring into petri plates. The Petri dishes were incubated at 27 ± 2°C until the appearance of mycelium.

Morphological characters of disease signs

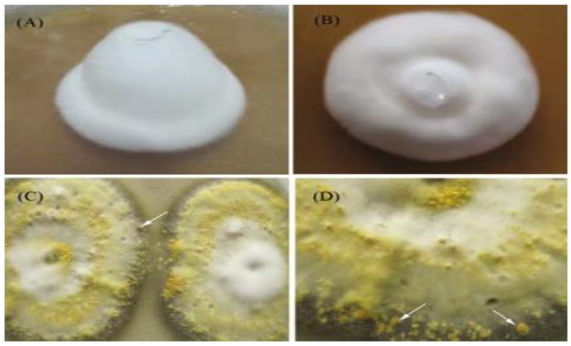


Figure 3. Colonies of *V. virens* on the XBZ solid medium. A) An isolate of *V. virens*, 10 days after inoculation. (B) The morphology of colony resembled a straw hat, days after inoculation. (C D) There were many mounds of chlamydospores (arrows) formed on the colony margin and a great number of chlamydospores dispersed on the whole colony, 40 days after inoculation.

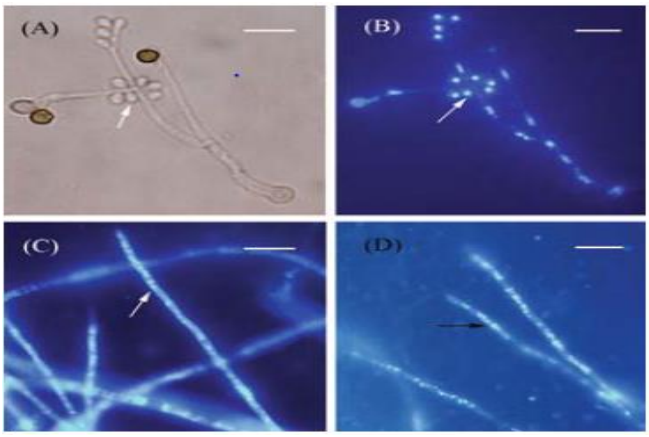


Figure 4. Chlamydospores of germinated *V. virens* and karyological observation. (A) The conidia are holoblastically and sympodially produced at the apex of each conidiophore cells. (B) Conidia were mononuclear (arrows). (C–D) Somatic hyphae were multinuclear (arrows).Bars: A–D=10 µm.

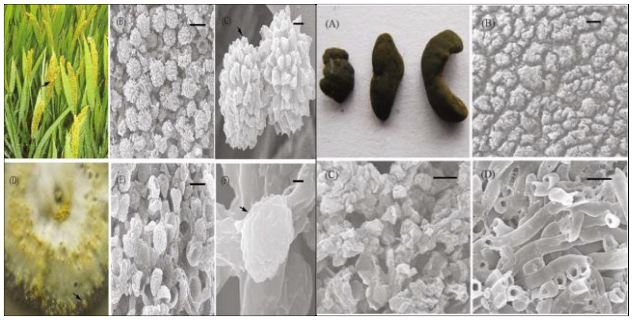


Figure 5. Symptom of rice false smut and scanning electron micrographs of *V. virens* chlamydospores came from natural false smut balls and laboratorial culture A) A naturally infected rice kernel (arrows). (B) Chlamydospores masses. (C) Higher magnification of the chlamydospores. (D) A large number of chlamydospores balls piled on the XBZ solid medium. (E) Chlamydospores masses. (F) Higher magnification of a chlamydospore,with wavy spines (arrows) were prominent on the chlamydospores surface. Bars: B, E=10 µm.C, F=1 µm. Figure 6. Scanning electron micrographs of *V. virens sclerotia.* (A) Sclerotia of *V. virens*, which appeared black horseshoe-shaped and irregular oblongor flat and sizes ranged from 2 to 20 mm. (B–C) Surface shape of asclerotium. (D) Internal structure of a sclerotium, comprising dense mycelium. Bars: B=5 µm. C–D=10 µm.

5. Mode of infection

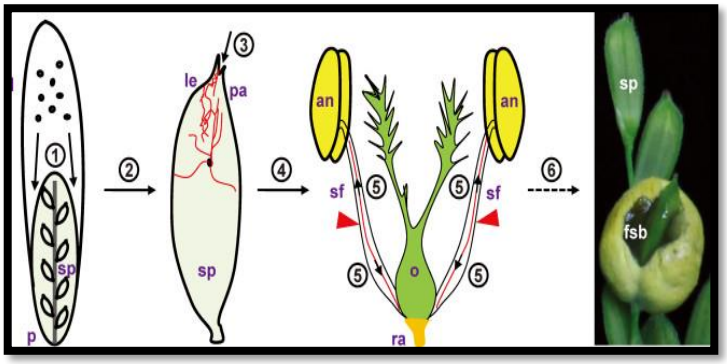


Figure 7. Modes of infection

Villosiclava virense (Vv) spores landing on the top of the second leaf (l) can enter the developing panicle (p) along with rainwater (Fig.9) 1. Subsequently, *Vv*spores are attached to the developing spikelet (sp) and germinate to produce hyphae 2. The hyphae extend into the inner space of the spikelet via the gap between the palea (pa) and lemma (le) 3. Primary infection sites are found in the

stamen filaments (sf) 4. where the hyphae extend intercellularly in both directions 5. Hyphae can extend into anthers (an) and reach the rachilla (ra), and intertwine with the ovary (o) and other floral organs. *Vv* hyphae acquire abundant nutrients to form false smut balls (fsb), hypothetically through hijacking of the rice nutrient reservoir 6. This step (arrow with dotted line) is of particular interest and requires further exploration. Red curved lines represent *V. virens* hyphae. Red arrowheads point to the primary infection sites at the stamen filaments.

Epidemiology and Disease cycle

Predisposing factors

High relative humidity and rainfall accompanied by cloudy days during flowering favoured the disease incidence and the high humidity and lower maximum temperature favours the disease. False smut incidence is favoured by relative low (around 20^0C) temperature and high relative humidity more than 90 per cent coupled with well distributed moderate rainfall during flowering also by late sowing and high soil fertility with N,P. and K at 100, 50, and 50 kg/ha.

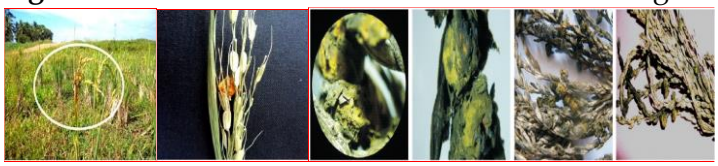
Alase *et al*., 2021 conducted field experiment during two consecutive kharif seasons (2019-20 and 2020-21) to find out the influence of weather parameters on disease development.

Off season survival of *Ustilaginoidea virens*

The pathogen survives as dormant structures such as sporeballs, chlamydospores, sclerotia etc. in soil, stubbles of the crop and on collateral hosts. It is reported that false smut disease survived on *Oryza officinalis* from India. Shetty and Shetty (1985) reported *Digitaria marginata*as the collateral host of *U. virens* from Dakshina Kannada district of Karnataka. False smut was also observed from India on *Panicum trypheron*

Echinochloa crusgalli, and *Imperata cylindrical* are the other reported collateral hosts of *U. virens*. Ratoon rice and weedy rice have some role to play in the off season active survival of the false smut pathogen, *U. virens* in Kerala. False smut disease of maize (*Zea mays* L.) has been observed in the Panchmahals and Dahod districts of Middle Gujarat, India during *kharif* 2013 (Shetty and Shetty, 1987).

Figure 8. False smut disease on ratoon rice emerged



from the stubbles of the previous crop and False smut disease on *Oryza spontanea*. 10. Yellow and black color smut balls produced by the false smut pathogen, *Ustilaginoidea virens* on the tassels of male flowers of maize.

Disease cycle of the fungus

As the fungus has been recorded on many grasses and wild rice, it is presumed that the spores produced on the collateral hosts become air-borne and serve as the main source of inoculum. Primary Infection is believed to be caused mainly by ascospores produced from the Sclerotia. Chlamydospores play an important role the secondary infection which is a major part of the disease cycle. Chlamydospores are air borne and are profusely present at the time heading of rice plant.

Infection of a few individual grains only lends support to the presumption that the infection is floral. If the infection takes place in the early stages of flower opening, the ovary is destroyed, whereas if the infection is later than the grain is set, the mycelium invades the endosperm and produces masses of the spores. The disease is not seed borne. Rainfall accompanied by cloudy days during the period between flowering and maturity of the grain increases the incidence of the disease.

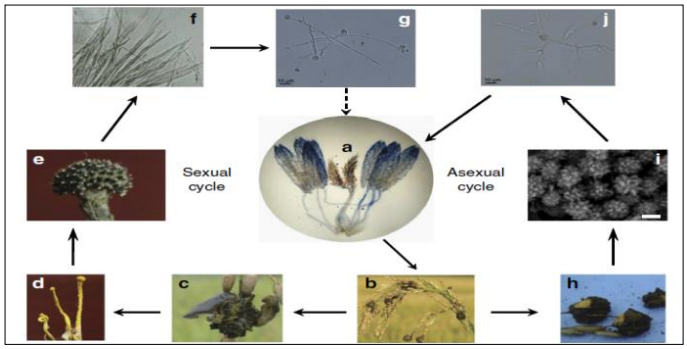


Figure 11. Major stages in the infection cycle of *U. virens*. a) Stamen filaments in the florets infected by *U. virens*. Hyphae were stained with trypan blue to show

primary infection sites. (b) False smut balls formed in the rice spikelets. (c) Sclerotia formed on the surface of spore balls. (d) Stroma produced by a germinating sclerotium. (e) Ascocarp formed on the stroma. (f) Asci. (g) Ascospore germination, Scale bar, 10 mm. (h) Spore balls. (i) Chlamydospores under scanning electron microscopy. Scale bar, 3 mm. (j) Chlamydospore germination.

Conclusion

False smut was recognized as a symbol of a bumper harvest and was categorized as a minor disease due to its sporadic occurrence. However, the disease has been observed in severe form since 2001. Hence to manage this disease future work should pay attention to developing a more rapid and effective system to evaluate rice resistance and susceptibility to the disease, screening of rice germplasm for disease-resistance breeding, studying the resistance inheritance and investigating the molecular mechanism of rice-false smut fungus interaction.

References

Alase S., Nagaraja A., Pramesh D. and Kumar M.P. (2021). Influence of Weather Parameters on False Smut Disease Development in Rice. Mysore Journal of Agricultural Sciences, 55 (4).

Dangi B., Khanal S. and Shah S. (2020). A review on rice false smut, it's distribution, identification and management practices. Acta Scientific Agriculture, 4: 48-54.

Huded S., Pramesh D., Chittaragi A., Sridhara S., Chidanandappa E., Prasannakumar M. K., Manjunatha C., Patil, B., Shil S., Pushpa H. D. and Raghunandana A. (2022). Spatial Distribution Patterns for Identifying Risk Areas Associated with False Smut Disease of Rice in Southern India. Agronomy, 12 (12), 2947.

Ladhalakshmi D., Laha G. S., Singh R., Karthikeyan A., Mangrauthia S. K., Sundaram R. M., Thukkaiyannan P. and Viraktamath B. C. (2012). Isolation and characterization of *Ustilaginoidea virens* and survey of false smut disease of rice in India. *Phytoparasitica.*, 40, 171-176.

Muniraju K. M., Pramesh D., Mallesh S.B., Mallikarjun K. and Guruprasad G. S. (2017). Disease severity and yield losses caused by false smut disease of rice in different rice ecosystems of Karnataka. *Int. J. Microbiol. Res.*, 9 (10), 963-966.

Rao G. P. and Reddy V. T. C. (1955). Occurrence of *Ustilaginoidea virens* (Cooke.)Takahashi. on *Oryza officinalis* Wall. Indian Phytopathology, 8, 72-73.

Sharanabasav H., Pramesh D., Prasannakumar M.K., Chidanandappa E., Yadav M.K., Ngangkham U., Parivallal B., Raghavendra B.T., Manjunatha C., Sharma S.K. and Karthik N. (2021). Morpho-molecular and mating-type locus diversity of *Ustilaginoidea virens*: an incitant of false smut of rice from Southern parts of India. *Journal of Applied Microbiology*, 131(5), 2372-2386.

Shetty S. A. and Shetty H. S. (1985). An alternative host for *Ustilaginodea virens* (Cooke) Takahashi, IRRI Newsletter., 10, 11.

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Rice Sheath Blight Disease: A Threat to Rice Crop

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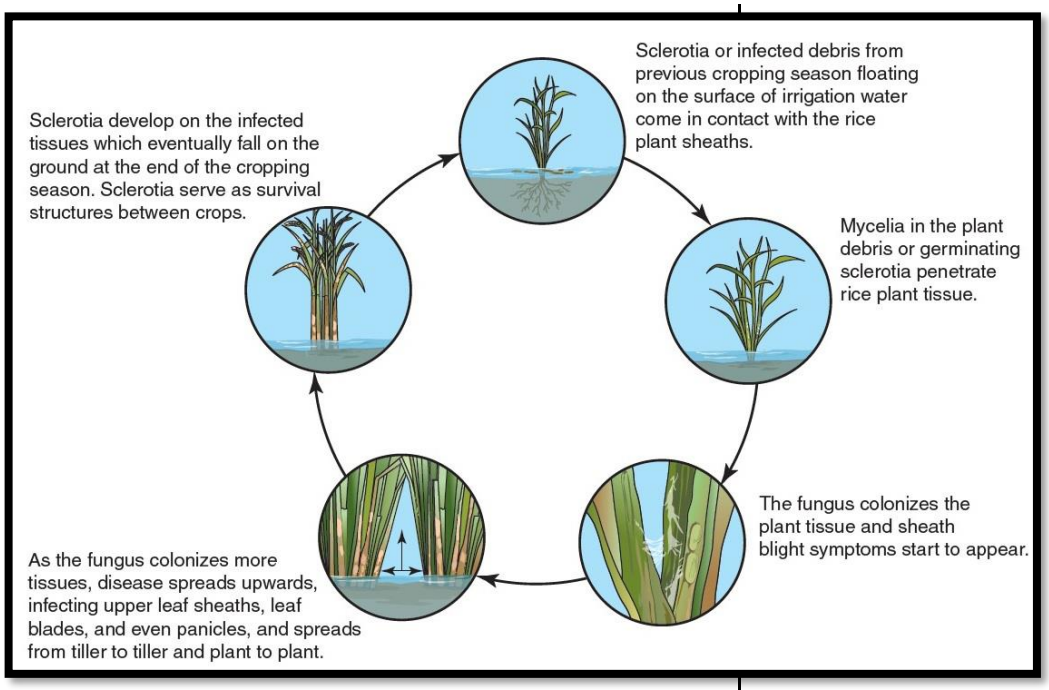
Diseases are the major factors for reduction in crop yield of rice, according to Margani and widadi (2018). There are number of pathogens cause loss in rice crop among them rice sheath blight (*Rhizoctonia solani*) disease is major concern and it causes considerable yield losses Prasad and Kumar (2011). Rice sheath blight can lead to significant yield losses if not properly managed. Severe infections can cause lodging, reduce grain quality, and result in economic losses for farmers. According to Jha *et al*. (2012) rice sheath blight is economically most important disease and causes about 25-30% yield losses per year in India. It is caused by the fungus *Rhizoctonia solani* particularly the anastomosis group AG1-IA. Rice sheath blight is a significant concern for rice farmers around the world, particularly in regions with warm and humid climates. This brief article aims to provide an understanding of the disease, its symptoms, disease cycle, impact, epidemiology, and management strategies.

Symptoms:

- The most noticeable symptoms of rice sheath blight appear during the later stages of rice growth.
- The symptoms include the development of elliptical or irregularly shaped lesions on leaf sheaths near water level, stems, and panicles of rice plants.
- The lesions on plant start as small water-soaked spots and then expand, becoming whitish-gray and surrounded by a dark brown border.
- The presence of several large lesions on a leaf sheath usually causes death of the whole leaf, and in severe cases all the leaves of a plant may be blighted in this way.
- The fungus can spread into the culms from early sheath infections and weaken the infected culms, resulting in the lodging and collapse of tillers.
- The infection extends to the inner sheaths resulting in death of the entire plant.
- Plants heavily infected in the early heading and grain filling growth stages produce poorly filled grain, especially in the lower part of the panicle.



Disease Cycle

- Rice sheath blight is soil borne disease but the pathogen also survives in crop residues and on infected plant material.
- It can infect rice plants at any growth stage but it is most common on early heading and grain filling growth stages.
- The fungus spreads through spore-producing structures called sclerotia, which can be moved by wind, water, and machinery.

Environmental Factors

- Warm and humid conditions are favourable for the development and spread of rice sheath blight.
- Relative humidity from 96 to 100% and temperature from 28-32 °C favours the disease development.
- Heavy rainfall, extended periods of leaf wetness, and high humidity can create ideal conditions for the disease to thrive.

Management

An integrated management approach, consisting of resistant or moderately resistant varieties, sound cultural practices, and foliar fungicide application is ideal for effective and economic control of sheath blight and associated yield losses. Varietal susceptibility, field disease history, timely scouting for the presence of the disease, and local weather conditions that favor the disease, are among the critical factors to be considered for making effective disease management decisions. Sheath blight develops at a rapid pace under favorable conditions. The disease should be monitored on a regular basis starting from the panicle differentiation stage until heading. Infection after heading may cause insignificant economic losses due to sheath blight. There are following points recommend for management of rice sheath blight.

- Avoid planting of rice continuously in the same field to reduce the buildup of the pathogen in the soil.
- Planting rice varieties that exhibit resistance to sheath blight can be an effective strategy.
- High seeding rate and overuse of nitrogen fertilizer usually increase stand and induce excessive vegetative growth and canopy density, creating a moist microclimate favourable for disease development. Therefore, avoiding high seeding rates and excessive application of fertilizers, especially nitrogen, can reduce the damage caused by sheath blight.
- Avoiding excessive water application can help to reduce humidity and minimize disease development.
- Combined application of *T. viride* at 5.0 kg and Validamycin at 2.0 l/ha showed effective management tactic (Daroga Singh *et al*., 2007).
- Seed treatment with *Pseudomonas fluorescens* + *Trichoderma viride* @ of 10g/kg of seed followed by seedling dip @ of 2.5 kg or products/ha

dissolved in 100 litres and dipping for 30 minutes.

- Soil application of P. fluorescens + *Trichoderma viride* @ of 2.5 kg/ha after 30 days of transplanting.
- The disease is soil borne hence application of FYM 12.5 t/ha or green manure 6.25 t/ha to promote antagonistic microflora in the soil.
- Practices such as balanced fertilization, proper plant spacing, and avoiding excessive irrigation can help reduce disease pressure.
- Avoid flow of irrigation water from infected fields to healthy fields.
- Spray of Propiconazole 13.9% + Difenoconazole 13.9% EC @ 1ml /liter of water.
- Spray of Thifluzamide 24 SC @ 1ml /liter of water (45 days after transplanting)

Conclusion

In summary, sheath blight is a significant threat to rice cultivation, causing substantial economic losses and reducing food security in affected regions. Thus, the disease is a critical challenge for rice growers globally, impacting yield, grain quality, and economic returns. Ongoing research efforts are crucial for developing sustainable management strategies, including resistant varieties and environmentally friendly approaches, to mitigate the threat of sheath blight and ensure food security in rice-dependent regions.

References

Margani, R., Widadi, S. 2018, March. Utilizing Bacillus to inhibit the growth and infection by sheath blight pathogen, *Rhizoctonia solani* in rice. In IOP Conference Series: Earth and Environmental Science (Vol. 142, No. 1, p. 012070). IOP Publishing.

Prasad, B. N., Kumar, M. R. 2011. Effect of non-volatile compounds produced by *Trichoderma* spp. on growth and sclerotial viability of *Rhizoctonia solani*, incitant of sheath blight of rice. Indian Journal of Fundamental and Applied Life Science, 1(2), 37-42.

Jha, A., Singh, K. M., Meena, M., Singh, R. 2012. Constraints of rainfed rice production in eastern India: An Overview. Available at SSRN 2061953.

Prasad, D., Singh, R., Singh, A. 2010. Management of sheath blight of rice with integrated nutrients. Indian Phytopathology, 63, 11-15.

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Genetic Analysis of Resistance Gene Against Plant Diseases

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Due to the severity of diseases out breaks around the world, plant diseases can significantly reduce crop production. Therefore, one of the primary goals of any crop improvement programme has always been the management of plant diseases. Genes for plant diseases resistance can recognise and fight against a pathogen and assist in a counter attack. Numerous plant R –genes have been employed in crop improvement programme in the past with varying degrees of success, and many of them are still being use today. Recent advances in genomic, bioinformatics and molecular biology techniques make it possible to manage R-genes effectively for the treatment of plant illnesses brought on by pathogens. The recent uses and future promise on R-genes in crop diseases management are outlined in this paper. Resistance to different pathogens that is induced by the R protein is often race-specific and only effective against pathogen strains that produce the cognate effector protein (Avr protein) that the R protein recognises. Frequently, this resistance is accompanied by a hypersensitive reaction (HR), which manifests as the rapid death of the invaded cell and occasionally, a few adjacent cells. It is important to analyse the structural and functional properties of plant resistance genes and R-gene loci in order to efficiently assemble a variety of resistance sources.

The activation of signals during plant pathogen interactions, which can occasionally lead to a quick defence reaction against a variety of plant infections, is a well-known process. This reaction aids the host plant in protecting itself against the disease's spread. The production of specialised host genes known as R-genes recognises certain pathogen effectors to initiate plant defence signalling. Many distinct plant resistance (R) genes have previously been identified and are effectively exploited in crop enhancement research projects. It is practical to use plant resistance genes instead of other means, such as pesticides or other chemical control approaches, to create disease-resistant types of plants.

Use of plant resistance genes in resistance breeding programmes has several advantages, including effective pathogen growth reduction, minimal host plant damage, no farmer input of pesticides, and most importantly, environmentally friendly nature of the process. similar plants. However, in the case of conventional breeding for resistance, the introduction of resistance genes from one species into the gene pool of another via repeated backcrossing is a lengthy process and typically occurs after several hybrid generations. It is anticipated that thorough functional analyses, cloning, characterisation, and genetic transformation of plant resistance genes will aid researchers in quickly finding solutions to these issues.

Molecular isolation of resistance gene

Resistance caused by genes (reviewed in Gabriel and Rolfe, 1990). According to this theory, the elicitors that the Avr genes produce act as ligands for the R genes' receptors. The isolation of R genes or their gene products wasn't made any easier by this paradigm, even though it may prove to be accurate in some situations (described below). It took the advent of tools for plant gene cloning with unknown structural or molecular functions to be successful in isolating R genes. The first real chance for success came from maize transposable elements, but early attempts failed due to a high incidence of spontaneous mutations in the R genes that were being targeted, including maize Rp1 (Bennetzen et al., 1988). Nevertheless, these efforts led to the development of a body of research that is still in its early stages on the biological importance of R gene mutability in the creation of new resistance specificities (e.g., Sudapak et al., 1993; see also Crute and Pink, 1996, in this issue, and the discussion below).

Instead, transposon tagging of the R gene Hm7 from maize, which differs functionally from

traditional Avr gene-dependent R genes, led to the first R gene cloning. The fungus pathogen Cochliobolus carbonum Race 1 strains are resistant to Hm1 (Johal and Briggs, 1992). Hm1 was discovered to encode a NADPH-dependent reductase that inactivates the powerful plant toxin generated by these fungal strains (Johal and Briggs, 1992; Meeleyeta, 1992) in a conclusive series of investigations. Because Hml's toxin-degrading method lacks the pathogen Avr genes, the triggering of hypersensitive plant cell death, or other markers of gene-for-gene interactions, studies of Hm1 unfortunately did not suggest a structure or function for classically described R genes. However, work on Hm1 revealed a crucial mechanistic paradigm for naturally occurring or manufactured plant disease resistance, despite the fact that toxin generation is a highly prevalent aspect of pathogen pathogenicity (see Walton, 1996, in this issue).

Numerous isolated R genes have now been successfully identified thanks to the development of positional cloning (chromosome walking) and heterologous transposon tagging technologies (this topic is also covered in Lamb, 1994; Briggs, 1995; Dangl, 1995; Michelmore, 1995; and Staskawicz et al., 1995). The cloned R genes for which published reports are available. The first Avr gene-specific R gene to be isolated was Pto of tomato, which confers resistance against Pseudomonas syringae pv tomato bacteria expressing the Avr gene (Martin et al., 2004). After Pto was isolated using a positional cloning technique, it was discovered that this gene encodes a protein with properties resembling those of serine-threonine protein kinases.

R-gene mediated pathogen resistance

The first step of infection involves the delivery of specific chemicals produced by phytopathogens known as "effectors"—encoded by the Avr (avirulence) genes—directly into the plant cells. In this case, the effectors in order to facilitate pathogen colonisation, host plant physiological states are altered, or host plant defences are interrupted. However, plants have since evolved a defence mechanism known as R-gene mediated pathogen resistance that is based on how host resistance proteins perceive these proteins.

A plant with a resistance gene fights pathogen races with the appropriate effectors in gene-for-gene interactions. A host plant develops a resistance response to a plant pathogen as a result of the effectors that are present in bacteria, viruses, nematodes, fungi, oomycetes, and insects

Major classes of R protein

In general, plant resistance genes can be categorised into eight classes based on the arrangement of their amino acid motifs and membrane structure cover multiple domains The bulk of R proteins contain the LRRs (Leucine Rich Repeats), which are components with a significant impact on recognition specificity.

Genes for cytoplasmic proteins with a nucleotide-binding site (NBS), a leucine-rich repeat (LRR), and a putative coiled coil domain (CC) at the N-terminus make up the first major class of R-genes. Examples of this type of resistance genes include the tomato Fusarium oxysporum resistance gene I2, the Arabidopsis P. syringae RPS2 and RPM1 resistance genes, and the *P. syringae* RPS2 and RPM1 resistance genes.

Cytoplasmic proteins with LRR and NBS motifs and an N-terminal domain that is homologous to the mammalian toll-interleukin-1 receptor (TIR) domain make up the second class of resistance genes. The cigarette Examples of this class include the N gene, flax L6 gene, and RPP5 gene. Extra cytoplasmic leucine rich repeats (eLRR), connected to a transmembrane domain (TrD), make up the third major class of resistance genes family lacking the NBS motif. Even though they are not directly engaged in pathogen identification and the activation of defence genes, eLRRs are known to play a significant function for some defence proteins, such as polygalacturonase inhibiting proteins (PGIPs). This class of resistance genes includes the *C. fulvum* resistance genes (Cf-9, Cf-4, and Cf-2) with an extracellular LRR (eLRR), a membrane spanning domain, and a short cytoplasmic C terminus. The fourth category includes the rice Xa21 Xanthomonas resistance gene. class of resistance

genes, which are made up of an intracellular serine-threonine kinase (KIN) domain, a transmembrane domain (TrD), and an extracellular LRR domain [252]. The putative extracellular LRRs, a PEST (Pro-Glu-Ser-Thr) protein degradation domain (found only in Ve2, not Ve1), and short proteins motifs (ECS) that may target the protein for receptor-mediated endocytosis are all components of the fifth class of resistance genes (e.g., tomato Ve1 and Ve2 genes). However, it has recently been suggested that these Ve1 and Ve2 proteins are PAMP receptors.

Challenges and future direction

ESTs, whole genome sequences, data on gene expression, and other types of experimental data have all been produced in great quantities by researchers thanks to the development of high throughput techniques and effective genomic approaches. Even so, there has been very modest advancement in our knowledge of how resistance gene's function. For instance, the structural underpinnings of pathogen identification are poorly understood. A reference set of sequences that can be utilised as a model for resistance genes, which typically cluster in genomic regions with a large number of homologs and pseudogenes, is currently insufficient. Another barrier is the challenges in conducting investigations on plant-pathogen interactions.

In addition to improving our understanding of plant defence signalling, the application of functional genomics methods for disease resistance may also provide new insights into the relationships between these signalling pathways and other plant processes. It would be foolish to anticipate a significant advance in impermeable broad-spectrum resistance, even as research into plant defence mechanisms as a whole is moving forward at a rapid rate. However, it is wise to plan for a variety of extremely helpful instruments working in conjunction with other control mechanisms to provide enough protection in specific situations.

Acknowledgement

I acknowledgement the authors who provided the all information for helping us to write this genetic analysis of resistance gene against plant diseases

Conflicts of Interest

The authors declare no conflict of interest

References

Abramovitch RB, Kim YJ, Chen S, Dickman MB, Martin GB. Pseudomonas type III effector AvrPtoB induces plant disease susceptibility by inhibition of host programmed cell death. EMBO J 2003; 22:60e9.

Acciarri N, Rotino GL, Tamietti G, Valentino D, Voltattorni S, Sabatini E. Molecular markers for Ve1 and Ve2 Verticillium resistance genes from Italian tomato germplasm. Plant Breed 2007; 126:617e21.

Albar L, Bangratz-Reyser M, Hebrard E, Ndjiondjop MN, Jones M, Ghesquiere A. Mutations in the eIF (iso)4G translation initiation factor confer high resistance of rice to Rice yellow mottle virus. Plant J 2006; 47:417e26.

Alfano JR, Collmer A. Bacterial pathogens in plants: life up against the wall. Plant Cell 1996; 8:1683e98.

Allen RL, Bittner-Eddy PD, Grenville-Briggs LJ, Meitz JC, Rehmany AP, Rose LE, et al. Host- parasite co-evolutionary conflict between Arabidopsis and downy mildew. Science 2004; 306:1957e60.

Armstrong MR, Whisson SC, Pritchard L, Bos JIB, Venter E, Avrova AO, et al. An ancestral oomycete locus contains late blight avirulence gene Avr3a, encoding a protein that is recognized in the host cytoplasm. Proc Natl Acad Sci USA 2005;102:7766e71.

Austin MJ, Muskett P, Kahn K, Feys BJ, Jones JD, Parker JE. Regulatory role of SGT1 in early R-gene-mediated plant defenses. Science 2002;295(5562): 2032e3.

Baker CM, Chitrakar R, Obulareddy N, Panchal S, Williams P, Melotto M. Molecular battles between plant and pathogenic bacteria in the phyllosphere. Braz J Med Biol Res 2010;43:698e704.

Baldauf SL, Roger AJ, Wenk-Siefert I, Doolittle WF. A kingdom-level phylogeny of eukaryotes based

on combined protein data. Science 2000;290: 972e7.

Ballvora A, Ercolano MR, Weiß J, Meksem K, Bormann C, Oberhagemann P, et al. The R1 gene for potato resistance to late blight (Phytophthora infestans) belongs to the leucine zipper/NBS/LRR class of plant resistance genes. Plant J 2002;30:361e71.

Bar-Joseph M, Marcus R, Lee A. The continuous challenge of citrus tristeza virus control. Annu Rev Phytopathol 1989;27:291e316.

Belfanti E, Silfverberg-Dilworth E, Tartarini S, Patocchi A, Barbieri M, Zhu J, et al. The HcrVf2 gene from a wild apple confers scab resistance to a transgenic cultivated variety. Proc Natl Acad Sci USA 2004;101:886e90.

Belkhadir Y, Subramaniam R, Dangl JL. Plant disease resistance protein signaling: NBS- LRR proteins and their partners. Curr Opin Plant Biol 2004;7: 391e9.

Bendahmane A, Kanyuka K, Rouppe van der Voort J, Van der Vossen E, Baulcombe DC. A high resolution molecular map around the Rx locus of potato: analysis of a complex locus in a tetraploid background. Theor Appl Genet 1999;98:679e89.

Bendahmane A, Kohm B, Dedi C, Baulcombe D. The coat protein of potato virus X is a strain-specific elicitor of Rx-mediated virus resistance in potato. Plant J 1995;8:933e41.

Bendahmane A, Querci M, Kanyuka K, Baulcombe DC. Agrobacterium transient expression system as a tool for disease resistance genes isolation: application to Rx2 locus in potato. Plant J 2000;21(1):73e81.

Bent AF, Kunkel BN, Dahlbeck D, Brown KL, Schmidt R, Giraudat J, et al. RPS2 of Arabidopsis thaliana: a leucine-rich repeat class of plant disease resistance genes. Science 1994;265:1856e60.

Bent AF. Plant disease resistance: function meets structure. Plant Cell 1996; 8:1757e71

Büschges R, Hollricher K, Panstruga R, Simons G, Wolter M, Frijters A, et al. The barley Mlo gene: a novel control element of plant pathogen resistance. Cell 1997;88:695e705.

Cai D, Kleine M, Kifle S, Harloff HJ, Sandal NN, Marcker KA, et al. Positional cloning of a gene for nematode resistance in sugar beet. Science 1997;275: 832e4.

CavaliereSmith T, Chao EE. Phylogeny and megasystematics of phagotrophic heterokonts (kingdom Chromista). J Mol Evol 2006;62:388e420.

CavaliereSmith T. Membrane heredity and early chloroplast evolution. Trends Plant Sci 2000;5:174e82.

Champouret N, Bouwmeester K, Rietman H, van der Lee T, Maliepaard C, Heupink A, et al. Phytophthora infestans isolates lacking class I ipiO variants are virulent on Rpi-blb1 potato. Mol Plant-Microbe Int 2009;22:1535e45.

Chen RG, Li HX, Zhang LY, Zhang JH, Xiao JH, Ye ZB. CaMi, a root-knot nematode resistance gene from hot pepper (Capsicum annuum L.) confers nematode resistance in tomato. Plant Cell Rep 2007;26:895e905.

Chen W, Provart NJ, Glazebrook J, Katagiri F, Chang HS, Eulgem T, et al. Expression profile matrix of Arabidopsis transcription factor genes suggests their putative functions in response to environmental stresses. Plant Cell 2002;14:559e74.

Chern MS, Fitzgerald HA, Yadav RC, Canlas PE, Dong X, Ronald PC. Evidence for a disease-resistance pathway in rice similar to the NPR1-mediated signaling pathway in Arabidopsis. Plant J 2001;27:101e13.

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Interdisciplinary Insights: Airborne Inoculum Monitoring and Epidemiology

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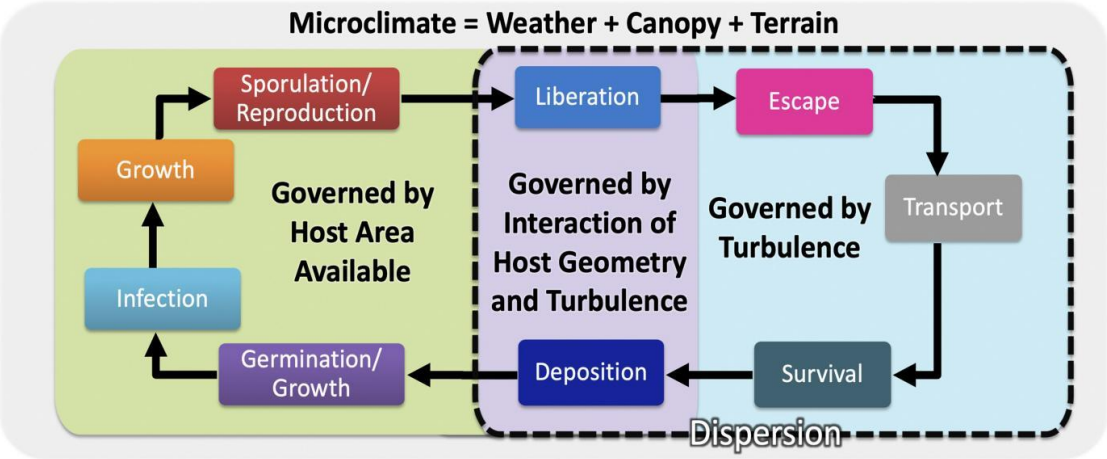

Global demand for pesticide-free food products is increasing rapidly. Crops of all types are under constant threat from various plant pathogens. To achieve adequate control with minimal pesticide use, close monitoring is imperative. Many plant pathogens spread through the air, so the atmosphere is composed of a wide variety of plant pathogenic and non-plant pathogenic organisms, particularly in agricultural environments. Air is the means of transport for many plant pathogens, some of which can travel thousands of kilometers while maintaining their viability and ability to cause new epidemics. Many plant pathogenic fungi are remarkably well adapted to airborne spread. The fact that fungal spores are spread by air currents has been known for almost as long as the existence of the spores themselves. The atmosphere in agricultural environments is therefore full of particles ranging in size from 0.1 µm for viruses to 100 µm for pollens. Monitoring spores and other particles in the air requires a specific field of scientific expertise, which is called aerobiology. Aerobiology has developed to a large extent in response to the need to know the quality of air in buildings and of pollen responsible for allergies in humans.

Purposes of sampling airborne fungal spores

Sampling airborne fungal spores serves various critical purposes in aerobiology. It enhances our understanding of airborne disease epidemiology on different scales and aids in modeling disease development and forecasting systems. Comparative epidemiology utilizes airborne inoculum data to study its role in disease progression under varying conditions. Combining aerobiological data with genetics allows for studying pathogen communities, including fungicide resistance and aggressiveness. Moreover, it supports biovigilance efforts to assess climate change impacts, emerging pathogens, and genetic diversity. Surveillance involves long-term monitoring of sporadic pathogens or new arrivals, while monitoring aids day-to-day disease management decisions. These strategies help optimize disease prevention and control measures, enhancing overall agricultural and environmental health.

Dispersal

Disease development is typically conceptualized by the disease triangle that represents interactions among the host, pathogen and environment. Dispersion is a spatiotemporal process that operates across numerous scales in space and time. Success of dispersion is dependent on the factors that influence liberation, escape, transport, survival and deposition of propagules.

Advantages of Airborne Spore Sampler Monitoring

- Early Disease Detection: Airborne spore sampler monitoring allows for the early detection of pathogens before visible symptoms appear on plants. This timely information enables growers to initiate control measures proactively, preventing disease outbreaks.

- Precision Control: By tracking the presence and concentration of airborne spores, growers can implement targeted and precise control measures. This reduces the need for broad-spectrum pesticide applications and minimizes environmental impact.
- Real-time Monitoring: Some modern airborne spore samplers provide real-time data, allowing growers to receive timely alerts and make informed decisions quickly. This is especially crucial in dynamic disease scenarios.
- Data-driven Decision Making: Airborne spore sampler data provides valuable insights into pathogen dynamics, helping growers make evidence-based decisions about the timing of treatments, planting, and other management practices.
- Risk Assessment: Monitoring spore concentrations helps in assessing disease risk and understanding disease development patterns. This knowledge guides the deployment of control strategies effectively.
- Integrated Pest Management (IPM): Airborne spore sampler data can be integrated into IPM strategies, promoting a holistic approach to disease management that considers various factors like cultural practices, weather conditions, and biological controls.
- Reduced Pesticide Use: With accurate monitoring, growers can optimize pesticide use, minimizing overuse and reducing the development of pesticide-resistant strains.
- Climate Change Adaptation: Airborne spore sampler data can aid in studying the impact of climate change on disease dynamics, allowing for adaptive management strategies to be developed.

Disadvantages of Airborne Spore Sampler Monitoring

- Technical Expertise: Proper operation and maintenance of airborne spore samplers require technical expertise, which might be a barrier for some growers.
- Equipment Costs: Acquiring and maintaining airborne spore sampler equipment can be expensive, particularly for smaller farms or regions with limited resources.
- Data Interpretation: Analyzing spore sampler data and translating it into actionable decisions can be complex, requiring knowledge of both plant pathology and data analysis.
- Limited Pathogen Coverage: Airborne spore samplers are designed to target specific pathogens or groups of pathogens. This limits their usefulness if a diverse range of pathogens needs monitoring.
- Variability: Spore concentration in the air can vary greatly due to factors such as weather conditions, topography, and local sources of inoculum. This variability can make data interpretation challenging.
- Limited Spatial Resolution: The spatial resolution of airborne spore sampler data might not capture fine-scale disease variation within a field. Additional localized monitoring may be necessary.

Conclusion

The understanding of aerobiology combined with the variations of pathogen-specific biology and disease epidemiology, can serve as a guide to designing improved monitoring approaches. By deploying specialized samplers, researchers have unlocked a wealth of information about spore concentrations, dispersion patterns and temporal dynamics. This information not only enhances our understanding of disease epidemiology, but also guides the development of innovative disease management strategies.

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Role of Antimicrobial Peptides for Plant Disease Management

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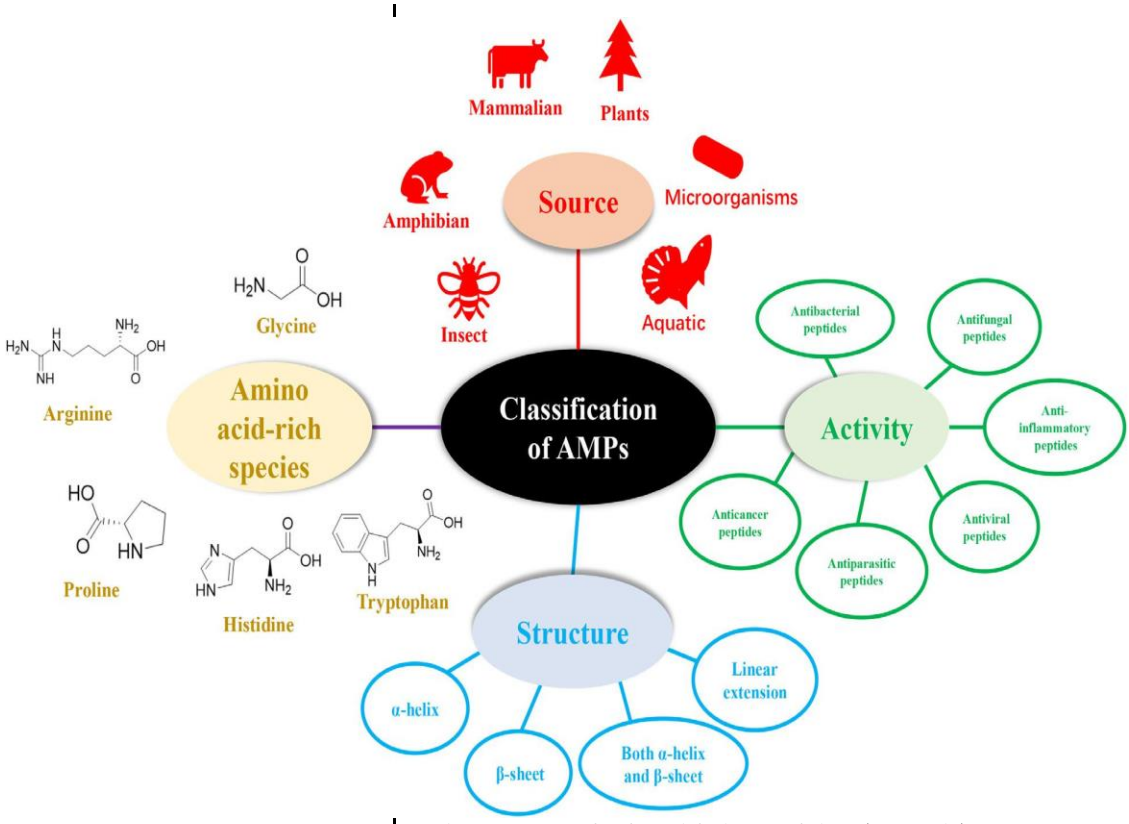
In the natural ecosystem, the plants being sessile they usually coexist in an environment rich in wide variety of microorganisms and pests. They have developed complex, sophisticated defence mechanisms that enable them to effectively defend against deleterious organisms such as virus, bacteria, fungi, nematodes and insects. These includes physical barriers against their spread and infection; chemical barriers-to inhibit pathogen growth and development.

Along with the self-defense of the plants against various pathogens chemicals like fungicides, bactericides and antibiotics are being sprayed exclusively. Application of these same fungicides and chemicals leads to resistance of the pathogen against such chemicals. Even after, all these influence of disease factors on plants, it still tries to survive. This might be because of self-defence of the plants against such pathogens. So, antimicrobial peptides (AMP's) are among the plant defence molecules which are one of the most common and prominent chemical barriers that plants have developed to resist the biotic and abiotic stresses. AMP's are part of innate immune system inherent in almost all life forms, including microorganisms, arthropods, animals and plants which contribute greatly to host defense against pathogens.



What are Antimicrobial peptides (AMP's)?

AMP's are small defence peptides naturally produced by a wide range of microorganisms. They are short sequence of amino acids with positive charged residues and diverse plant proteins with amphipathic nature which helps them to interact with pathogen's membrane and affects its permeability. Act as first line of defence against phytopathogens.

Classification of antimicrobial peptides (AMP'S)

Structure of AMP's-

Antimicrobial peptides are made up of peptides. The basic structure of peptides consists of amino acids linked by carboxyl group of one amino group [NH_2] of other to produce peptide bond. And secondary structure of AMP's consists of α-helix, β-sheets connected by disulfide bonds (S=S), random coils and mixed structure.

Mechanism of action of AMP's-

Antimicrobial peptides (AMPs) are thought to combat microbes by interacting with their cell

membranes, although the exact mechanism remains partially understood. Typically, these peptides, which carry a positive charge, engage with the negatively charged membranes of bacteria, enhancing permeability and triggering swift cell death. The AMPs' specific properties like sequence, size, charge and hydrophobicity influence their activity. Hydrophilic, positively charged segments enable them to interact with microbial membranes, disrupting transmembrane potential and pH gradients, disturbing osmotic regulation, and inhibiting cell respiration, ultimately causing microbial demise. AMP-cell membrane interactions occur through various models, including barrel-stave pore, carpet mechanism, toroidal pore and disordered toroidal pore.

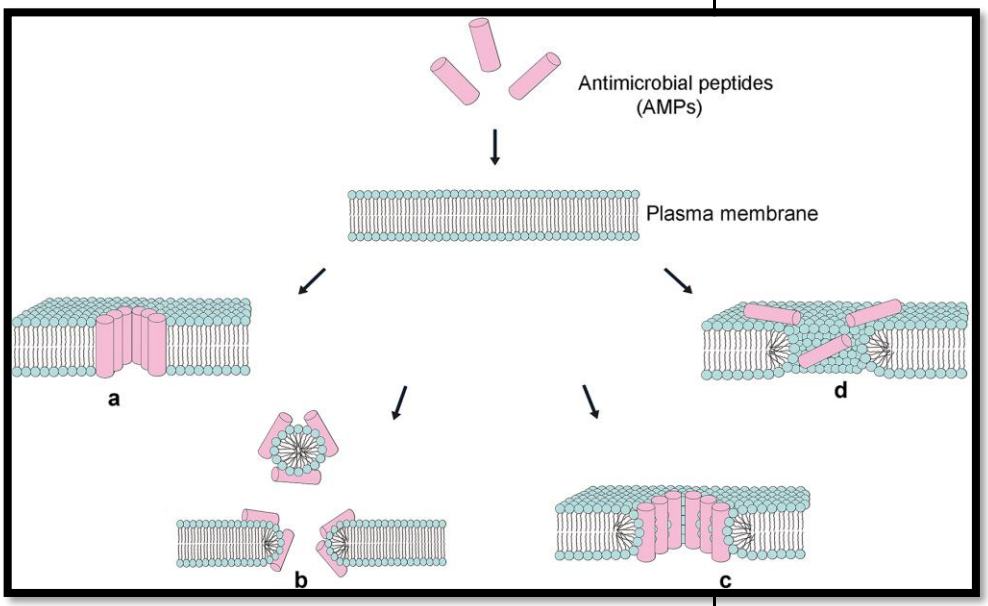


Figure 2: A. Barrel-Stave pore; B. Carpet mechanism; C. Toroidal pore; D. Disordered toroidal pore.

Functions of AMP's

1. Interaction with membrane
2. Affect biological activity
3. Transfer acyl monomer
4. Altering cell signals
5. Bursting of hyphal tip
6. Binding with phosphoipids
7. Inhibition of cell wall synthesis

Conclusion

Antimicrobial peptides (AMPs) of plant origin have a variety of amino acid compositions and structures, many of which exhibit potent broad spectrum antimicrobial activities and prove capable of killing microbes rapidly. Plant AMPs are thus potentially valuable natural alternative to chemical antibiotics for use in both human healthcare and in agriculture to protect plants and animals from disease.

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Bioengineering in Crop Disease Management

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Crop diseases are a major threat to global food security, resulting in yield reductions and economic losses for the farmers. Traditional agricultural disease management strategies have limits, prompting the development of bioengineering technologies. These methods involve the inserting resistant genes into crops, using RNA interference (RNAi) technology, genome editing. With bioengineered crops showing the both successes and challenges. As the global population continues to grow, the demand for the food increases, and the threat of crop diseases becomes more significant. The potential of the bioengineering in crop disease management is vast, with the emerging technologies providing promising prospects for the future. Bioengineering technologies provide a more sustainable and environmentally friendly alternative to traditional agricultural disease management strategies, assuring food security for the future generations. The use of resistance genes, RNAi, genome editing, can significantly reduce the impact of the crop diseases on the yields and promote the sustainable agriculture practices.

Crop diseases are a major threat to global food security, affecting the yield and quality of crops. Bioengineering approaches offer promising solutions for the disease management, including the development of disease-resistant crops and the precision control strategies. In recent years, there has been a surge of interest in the application of engineering principles to address crop disease challenges. Disease management practices can help to ensure the sustainability by protecting crop yields, maintaining and improving the crop producer profitability, lowering losses along the distribution chain, and reducing the negative environmental impacts of diseases and the disease management. Crop disease management promotes the sustainability by enhancing food security for both farmers and consumers(Andersen,2000). As the global population continues to expand, utilizing an integrated approach to the crop disease management will be critically important for agricultural sustainability and environmental protection. Bioengineered crops that provide protection against the insects and diseases, or tolerance to herbicides (Anderson et al.,2019). In the same way that the pathogen populations adjust to conventionally cultivated resistance, we can expect the same in reaction to the deployment of engineered resistance mechanisms minimising disease pressure through integrated disease management continues to be an important technique for minimising selection pressure towards resistant characteristics. Thus, GE traits should be used in conjunction with appropriate disease management practices (Lamichhane et al.,2016). In the past few years, advances in crop breeding have provided a number of new technologies in the food and agriculture industry (Ali et al.,2021). Approaches to genetic crop improvement cover a wide range of strategies, from the simple phenotypic selection through genome editing.

Bioengineering Strategies for Plant Disease Resistance

There is a wide variety of published strategies for engineering disease resistance, and ongoing research and expanding genetic resources (Cochrane et al., 2010) are likely to lead to additional strategies. Furthermore, several applications are possible within the majority of those strategies. These findings show that bioengineering opens up a wide reservoir of genetic possibilities for future generations. This will enable disease resistance breeding to stay very dynamic in the face of pathogen adaptation to virulence on resistant crops. While it is difficult to predict which Bioengineering techniques will have the most influence on crop disease control in the next decades, all of those discussed below show promise and, in the author's opinion, warrant further research. Some have shown proof-of-concept, while others have been field-tested and, in some cases, introgressed into commercially viable variants. All strategies described below take advantage of and in most cases, mimic processes that occur in Nature (Vincelli., 2016).

RNAi for Improving Disease Resistance in Plants

RNAi has long been the go-to method for gene silencing in a variety of biological domains, but it has also been widely exploited as a plant-protection platform. Plants, as sessile organisms, must tolerate a wide range of biotic and abiotic stressors that have a negative impact on growth and output. Depending on the environmental conditions, several biotic stressors such as insects, fungus, and nematodes attack their host plants and cause significant yield loss. Insects, like plants, have RNAi machinery that is mostly used to defend against viruses (Matranga and Zamore, 2007). Exogenous application of dsRNAs in plants via dsRNA injection or feeding insects dsRNA-containing artificial diets (Baum et al., 2007) or developing transgenic plants expressing dsRNAs targeting vital insect genes (Vélez and Fishilevich, 2018; Zotti et al., 2018; Di Lelio et al., 2022). Once this fact was revealed, researchers began focusing their efforts on strengthening the integrated pest control system by synthesising dsRNAs that target insects that cause significant agricultural damage. We've talked about many ways that use "RNAi-as the central mechanism" to boost disease resistance in plants.

Conclusion

In conclusion, engineering disease resistance in crops involves a range of strategies that leverage natural defence mechanisms or mimic processes found in nature. These strategies have the potential to increase crop disease resistance, reduce dependency on chemical pesticides, and improve agricultural sustainability. Increased plant awareness of infection via PAMP receptor gene transfer broadens the variety of pathogens that can that can trigger a natural defense response in crops. This method has resulted in enhanced resistance to bacterial infections . Antimicrobial substances can be produced in agricultural plants by adding genes encoding antimicrobial peptides or enzymes, which can lower pathogen activity and increase disease resistance. This approach has been effective against bacterial and fungal infections. The use of RNA interference (RNAi) to silence essential pathogen genes selectively targets specific genes in pathogens, limiting their ability to cause disease. This method has protected crops from destructive pathogens. Engineering the CRISPR/Cas immune system in plants provides a targeted immune response against invading DNA from pathogens, particularly DNA viruses. This technique shows promise for combating challenging viruses that are difficult to control through traditional breeding methods. While these strategies hold great potential, considerations of public acceptability and further research are necessary, as some involve genetic modification and the introduction of foreign DNA sequences. Overall, crop disease resistance techniques bring up a vast pool of genetic potential for future generations. By lowering the use of chemical pesticides, boosting crop yields, and permitting dynamic responses to disease adaptation, they provide hope for sustainable agriculture. Continued research and development of these solutions will help us protect crops and ensure food security.

References

Pinstrup-Andersen, P. (2000). The future world food situation and the role of plant diseases. *Canadian Journal of Plant Pathology*, *22*(4), 321-331

Anderson, J. A., Ellsworth, P. C., Faria, J. C., Head, G. P., Owen, M. D., Pilcher, C. D., ... & Meissle, M. (2019). Genetically engineered crops: importance of diversified integrated pest management for agricultural sustainability. Frontiers in bioengineering and biotechnology, 7, 24.

Lamichhane, J.R.; Dachbrodt-Saaydeh, S.; Kudsk, P.; Messéan, A. Toward a reduced reliance on conventional pesticides in European agriculture. *Plant Dis.* 2016, *100*, 10–24.

Ali, Q., Ahmar, S., Sohail, M. A., Kamran, M., Ali, M., Saleem, M. H., ... & Ali, S. (2021).

Research advances and applications of biosensing technology for the diagnosis of pathogens in sustainable agriculture. *Environmental Science and Pollution Research*, *28*, 9002-9019.

Ferreira, S.A.; Pitz, K.Y.; Manshardt, R.; Zee, F.; Fitch, M.; Gonsalves, D. Virus coat protein transgenic papaya provides practical control of papaya ringspot virus in Hawaii. *Plant Dis.* 2002

Collotta, M.; Bertazzi, P.A.; Bollati, V. Epigenetics and pesticides. *Toxicology* 2013, *307*, 35–41.

Dutka, A.; McNulty, A.; Williamson, S.M. A new threat to bees? Entomopathogenic nematodes used in biological pest control cause rapid mortality in *Bombus terrestris*. *PeerJ* 2015, *3*, e1413.

Baum, J.A.; Bogaert, T.; Clinton, W.; Heck, G.R.; Feldmann, P.; Ilagan, O.; Johnson, S.; Plaetinck, G.; Munyikwa, T.; Pleau, M.; *et al.* Control of coleopteran insect pests through RNA interference. *Nat. Biotechnol.* 2007, *25*, 1322–1326.

Shan, Q.; Wang, Y.; Li, J.; Zhang, Y.; Chen, K.; Liang, Z.; Zhang, K.; Liu, J.; Xi, J.J.; Qiu, J.L.; Gao, C. Targeted genome modification of crop plants using a CRISPR-Cas system. *Nat. Biotechnol.* 2013, *31*, 686–688.

Ali, Z.; Abulfaraj, A.; Idris, A.; Ali, S.; Tashkandi, M.; Mahfouz, M.M. CRISPR/Cas9 mediated viral interference in plants. *Genome Biol.* 2015, *16*, 238.

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Systemic Induced Resistance: A Strategy in Target of Achieving Sustainable Agriculture Goals through Plant Disease Management

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When just these chemical treatments were used, resistance developed, pests returned, residues accumulated, and the environment became contaminated. Plants have developed numerous defence mechanisms to stave off predators such as insects and diseases. Systemic acquired resistance (SAR) is a form of induced resistance that can develop in plants after they are exposed to elicitors from pathogenic, avirulent, or nonpathogenic microbes or synthetic chemical stimuli like chitosan or salicylic acid (SA). According to (Gozzo and Faoro, 2013).

Systemic acquired resistance (SAR) and induced systemic resistance (ISR) are two categories of induced resistance. Phenotypically, ISR is similar to pathogen-SAR because it increases resistance to pathogens such fungi, bacteria, viruses, and nematodes (Ran et al., 2005). Localised acquired resistance (LAR) and systemic acquired resistance (ISR, SAR) were initially defined by Ross (1961).

Diseases reduce crop yields and quality, and the harvest may contain poisons from microbes. In the past, plant diseases have triggered severe economic and food shortages, and they still play a major role in today's declining worldwide crop supply. Multiple phytochemical pesticides are being employed extensively to guarantee an adequate production and harvest quality. However, pesticides have harmful effects on food production, ecosystems, and human health.

Most current methods of protecting plants against disease and pests involve the use of harmful chemicals that are bad for the environment. Induced resistance, which makes use of plants' natural defence systems, is an alternative, unorthodox, and environmentally responsible form of plant protection.

Incorporating SAR into farming practises has the potential to lessen reliance on chemical pesticides, which is a win for eco-friendly farming. Plants can develop induced resistance when the expression of their innate defence systems against pathogens is stimulated. Pathogens that trigger hypersensitive necrotic reactions, avirulent or attenuated pathogenic strains, elicitors of pathogenic strains (proteins, glucans, lipids), and abiotic elicitors such as 2,6-dichloroisonicotinic acid (INA), benzathiadiazole (BTH), and -aminobutyric acid (BABA) are all potential triggers.

However, SAR may take several days to develop across the entire host plant (Kuc, 1982). Induced buildup of reactive oxygen species (ROS) has been postulated as an integrator between SA and ABA signals in the regulation of stomatal closure (Miura et al., 2013). Due to their roles in stomatal closure, SA and ABA have been hypothesised to mediate drought resistance.

Exogenous induction of SAR can be achieved by administering either the natural defence hormone SA or its synthetic equivalents 2,6-dichloroisonicotinic acid (INA) or benzothiadiazole S-methyl ester (BTH). SAR provides protection from a wide variety of pathogens, including bacteria, viruses, fungi, and oomycetes. The immunological "memory" that SAR imparts to plants may last for several weeks, months, or even the entire growth season. SAR, in contrast to ETI, encourages cell survival and is unrelated to programmed cell death.

SAR is predominantly mediated by and dependent on SA, since it was eliminated in the npr1, ics1, and other SA-accumulating mutants (Gozzo and Faoro, 2013; Kachroo and Robin). Many man-made chemicals, including salicylic acid, BTH (an SA analogue), and probenazole, have been linked to SAR. They play a significant role in the field of crop protection as chemical plant immunity activators. According to Kachroo and Robin (2013), many inducers of SAR signalling prime for SA accumulation in systemic tissues via a network of shared nodes.

Biotrophic infections were formerly assumed to be the primary focus of SA-dependent immune responses, as stated by Glazebrook (2005). Gozzo and

Faoro (2013) state that SAR is successful in combating several pathogens, nematodes, and parasitic plants. SAR is associated with a plethora of mobile transmissions. The most extensively researched mobile signal is MeSA, which is produced as a volatile emission during infection and is required for SAR (Park et al., 2007).

Instead of changing the genome (via mutations or the introduction of foreign genetic material), induced resistance relies on the manifestation of dormant genetic information within the plant, making it more physiologically safe. Topics covered include receptor-elicitor interactions, signal transduction pathways, and SAR gene expression as they pertain to the molecular underpinnings of induced resistance.

Understanding the SAR procedure has made great strides recently. The Arabidopsis model plant was used to determine that the "isochorismate (ICS) pathway" is the primary source of SA during SAR. In response to SA, the nucleus-localized positive regulator protein NPR1 interacts with TGA transcription factors (TFs) to activate SAR and induce the expression of defense genes. In their 2007 paper, Vasyukova and Ozeretskovskaya summarised what is known about SA's role in plant resistance.

The SA-dependent pathway relies on SA as a signalling molecule. The ability of SA to inhibit enzymes in the plant's antioxidant system is crucial to comprehending how SA builds resistance in plants by causing an accumulation of active oxygen species and the activation of defence genes.

As a result of redox changes induced by SA, NPR1 is transformed from inactive, disulfide-bound oligomers into functional monomers in the cytoplasm. NPR1 monomers localise to the nucleus and interact with the TGA family of basic leucine zipper TFs, resulting in the expression of several SA-dependent genes. WRKY TFs appear to play an important role in SA defensive responses as activators and repressors of SA transcription, either in parallel with or downstream of NPR1 (Wang et al., 2006). Although it is now clear that effectors can suppress SA defence, it is not yet clear how the various effectors link up with and alter SA signals (Loake and Grant, 2007).

Enhanced resistance to nematodes, bacteria, viruses, and fungi is made possible by SAR. Exposure to elicitors such as pathogenic, nonpathogenic, or virulent microbes, or synthetic chemical stimuli like chitosan or salicylic acid (SA), can cause a plant to develop systemic acquired resistance, a type of induced resistance that is functional throughout the plant. However, it may take several days for SAR to travel throughout the host plant.

To begin SAR, mobile signals must be generated at the location of local infection within four to six hours of the onset of illness. After reaching the systemic tissues (perhaps via the phloem), the signals trigger the defensive response. Salicylic acid (SA) and its methylated equivalent, MeSA, Jasmonic acid, Auxin, Pipecolic acid, Pip, Dehdryoabietinal, DA, Azelaic acid, AzA, and BABA have all been found to cause SAR.

Regulation of cellular redox and NPR1 nuclear translocation in response to SA accumulation is mediated by thioredoxins (TRXs) and S-nitrosoglutathione (GSNO). NPR3 and NPR4 are SA receptor proteins that regulate the nuclear concentration of NPR1. To facilitate PCD and ETI, a high concentration of SA is required at the site of local infection, while a moderate concentration of SA in the surrounding cells restricts NPR1-NPR4 contact, leading to NPR1 accumulation.

Protein secretion, antimicrobial PR proteins including PR1, PR2, and PR5, and resistance to secondary infection are all aided by the ER genes that NPR1 activates through interactions with transcription factors (TFs). Markers of the SAR primed state include H3K9 acetylation (Ac) and H3K4 methylation (Me) at SAR-associated gene promoters.

The activation of plant defence genes and the maintenance of genome stability in the current generation and in future generations may involve DNA methylation, proteins that control chromatin structure like SNI1, DNA repair like RAD51 and BRCA2, and other biological processes. Salicylic acid (SA), methyl salicylic acid (MeSA), azelaic acid (AzA), glycerol-3-phosphate (G3P), and the abietane diterpenoid dehydroabietinal (DA) are only some of the signals that can be produced in response to an avirulent infection.

These signals cause the uninoculated distal tissue to produce antimicrobial PR (pathogenesis related) genes, protecting the rest of the plant against infection. A SAR describes this kind of situation. Reducing the need for pesticides and other plant protection products (PPP) through the phenomena of systemic acquired resistance (SAR) is encouraging. Plants use SAR, a form of innate immunity, to fight against pathogens. It strengthens the plant's immune system, making it more resistant to pathogens of all kinds. It's possible that the plant's SAR response will be long-lasting and can be passed on to other pathogens.

Prior infection or treatment with elicitors primes the plant's defences for enhanced resistance (or tolerance) to a pathogen in systemic acquired resistance (SAR) and induced systemic resistance (ISR) (Vallad and Goodman, 2004). In contrast to the broad-spectrum disease resistance (SAR) associated with induced systemic resistance (ISR), which is mediated by a jasmonate/ethylene-sensitive pathway, SAR is characterised by and mediated by a salicylic acid (SA) dependent process (Mauch-Mani & Metraux, 1998).

However, Metraux (2001) argues that SAR and ISR are synonymous. Inducing SAR in plants protects them from infections; benzothiadiazole (BTH) and -aminobutyric acid (BABA) are two examples (Zimmerli, 2001; Tonne, 2009; Slaughter, 2012). Exogenous application of specific inducers results in a comparable response in plants, as demonstrated by Harman (2004).

Plants undergo priming during the induction of SAR, a period during which the prolonged presence of the pathogen activates the plant's defences. Under heavy disease pressure, primed plants fare better than non-primed plants or plants that express defences. In response to initial infection, plants increase their defence capacity by upregulating the expression of defence genes and producing new antimicrobial compounds such PR proteins in previously uninfected tissue (Ramos Solano, 2008).

One approach to creating SAR involves modifying plants to express SAR genes in a constitutive manner. Recent years, however, have seen the development of new theories concerning the costs of the constitutive existence of protective qualities at fixed high levels (Heil, 2000). Plants that put more resources on defence are expected to be less successful in dangerous environments. Because defence expenditures are only undertaken under conditions where they are truly necessary, phenotypic plasticity, which results in SAR responses, may have evolved solely to minimise costs. This may greatly affect the development of plant defences.

In order to prevent harm to people, animals, or the environment from mulberry disease treatments, it is crucial that SAR chemicals be widely disseminated. A model to promote the use of these chemicals is required to increase the profitability of sericulture. This strategy for controlling pests and illnesses has positive ecological effects. Fungal infection and insect damage appear to activate chitinase genes in the mulberry plant, suggesting that these chitinases help the mulberry plant overcome these dangers (Wang et al., 2015).

Conclusion

Plants' induced resistance is currently little understood, but it provides fresh information on defence mechanisms and has potential as a technique for ecologically friendly disease control and sustainable agriculture. It remains challenging for both theoretical and applied study.

Systemic induced resistance is an important strategy for implementing IPM by bolstering plants' inherent defences. Synthetic chemicals have opened up useful avenues for developing systemic resistance in plants, which can be used for the treatment of plant diseases. When SAR inducers are widely used, they have fewer negative consequences on people and the planet. There isn't a single SAR drug that isn't at least as effective as a fungicide in protecting against diseases.

Reference

Glazebrook J. Contrasting mechanisms of defense against biotrophic and necrotrophic pathogens. Annual Review of Phytopathology 2005;43:205–27

Gozzo F, Faoro F. Systemic acquired resistance (50 years after discovery) moving from the lab to the field. Journal of Agriculture and Food Chemistry. 2013; 61(51):12473-91

Harman GE, Howell CR, Viterbo A, Chet I, Lorito M, Trichoderma species - opportunistic, a virulent plant symbionts, Nature Reviews Microbiology, 2, 2004, 43-56

Heil M, Hilpert A, Kaiser W, Linsenmair KE. Reduced growth and seed set following chemical induction of pathogen defence: does systemic acquired resistance (SAR) incur allocation costs? Journal of Ecology 2000;88:645–54

Kachroo A, Robin GP. Systemic signaling during plant defense. Current Opinion in Plant Biology 2013; 16:527–33

Kuc J. Induced immunity to plant disease. Bioscience. 1982; 32:854-860

Loake G, Grant M (2007) Salicylic acid in plant defence – the players and protagonists. Current Opinion in Plant Biology 10, 466-472

Mauch-Mani B, Metraux JP, Salicylic acid and systemic acquired resistance to pathogen attack, Annals of Botany, 82, 1998, 535-540

Metraux JP, Systemic acquired resistance and salicylic acid: current state of knowledge, European Journal of Plant Pathology, 107, 2001, 13–18

Miura K, Okamoto, H, Okuma E, Shiba H, Kamada H, Hasegawa PM.et al, SIZ1 deficiency causes reduced stomatal aperture and enhanced drought tolerance via controlling salicylic acid-induced accumulation of reactive oxygen species in Arabidopsis. Plant Journal, 2013; 73:91-104

Slaughter A, Daniel X, Flors V, Luna E, Hohn B, Mauch-Mani B, Descendants of Primed Arabidopsis Plants Exhibit Resistance to Biotic Stress, Plant Physiology, 158 (2), 2012, 835–843

Park SW, Kaimoyo E, Kumar D, Mosher S, Klessig DF. Methyl salicylate is a critical mobile signal for plant systemic acquired resistance. Science 2007; 318:113–6

Ramos Solano B, Barriuso Maicas J, Pereyra de la Iglesia MT, Domenech J, Gutiérrez Mañero FJ, Systemic disease protection elicited by plant growth promoting rhizobacteria strains: relationship between metabolic responses, systemic disease protection, and biotic elicitors, Phytopathology, 4, 2008, 451- 457

Ran LX, Vanloon LC Barker PAHM. No role for bacterially produced salicylic acid in rhizobacterial induction of systemic resistance in Arabidopsis. Phytopathology, 2005; 95:1349-1355

Ross AF.Localized acquired resistance to plant virus infection in hypersensitive hosts. Virology, 1961; 14: 329-339

Ton J, Ent SVD, Hulten MV, Pozo M, Oosten VV, Van Loon LC, Mauch-Mani B, Turlings TCJ, Pieterse CMJ, Priming as a mechanism behind induced resistance against pathogens, insects and abiotic stress, IOBC/wprs Bulletin, 44, 2009, 3-13

Vallad GE, Goodman RM, Systemic acquired resistance and induced systemic resistance in conventional agriculture, Crop Science, 44, 2004, 1920-1934

Vasyukova NI, Ozeretskovskaya OL (2007) Induced plant resistance and Salicylic acid: A review. Applied Biochemistry and Microbiology 43, 367-373

Wang X, Ningjia He N, Zeng Q, Xiang Z. Identification and expression analyses of chitinase genes in mulberry (Morus L.) plants. Plant Omics Journal. 2015; 8(2):183- 189

Zimmerli L, Métraux JP, Mauch-Mani B, b-Aminobutyric acid-induced protection of Arabidopsis against the necrotrophic fungus Botrytis cinerea, Plant Physiology, 126, 2001, 517-523.

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