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A STEP TOWARDS AGRICULTURE

Agri Roots
e-Magazine

A TRIBUTE TO THE FATHER OF INDIA'S GREEN REVOLUTION

-End of Legacy (1925-2023)

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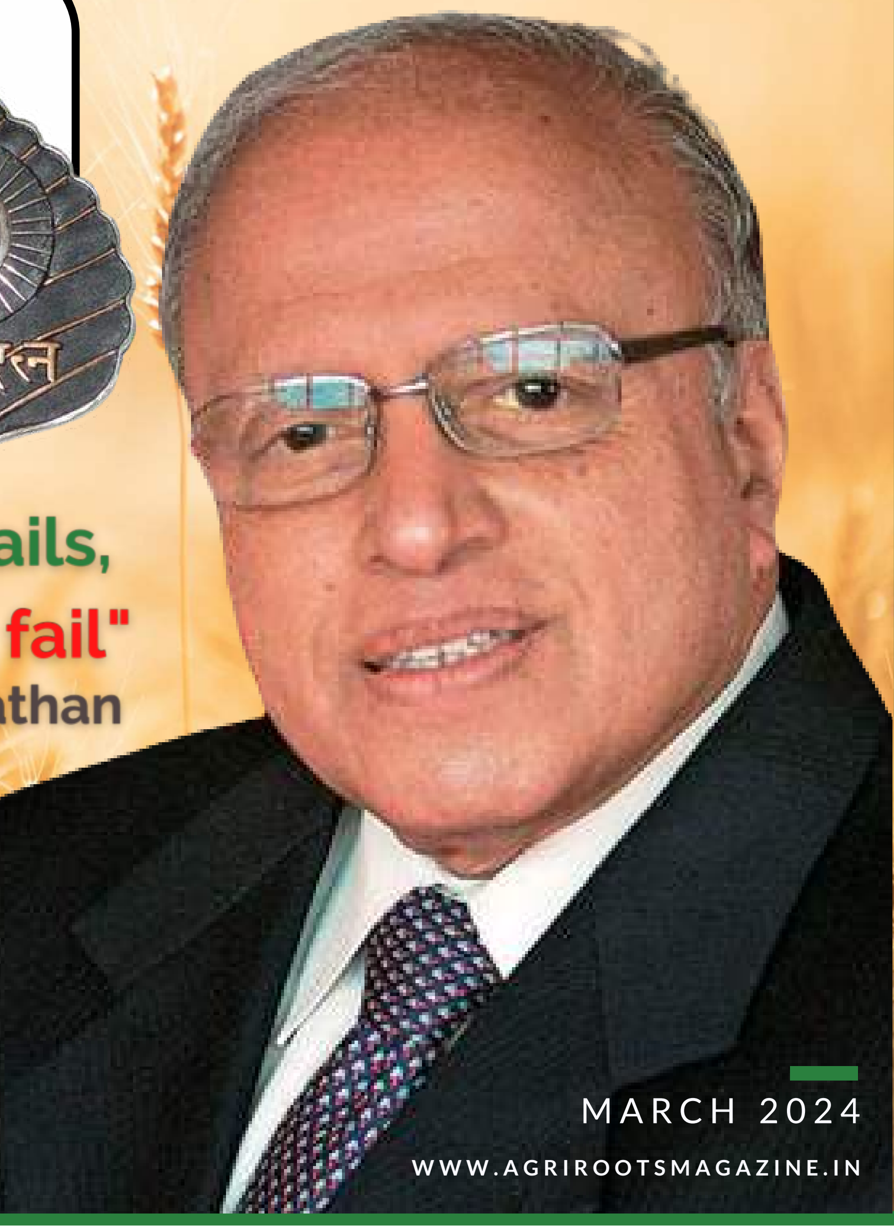

"If the agriculture fails, everything else will fail"
-M.S. Swaminathan

"GROWING A SUSTAINABLE FUTURE WITH THE GREEN REVOLUTION"

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from the editor

Dr. M.S. Swaminathan, a renowned Indian scientist and the Father of the Green Revolution in India, has been conferred with the prestigious Bharat Ratna. This honor, India's highest civilian award, recognizes Dr. Swaminathan's exceptional contributions to agriculture and his pivotal role in transforming the country's agricultural landscape.

Dr. Swaminathan's pioneering work in the field of agriculture has had a profound impact on India's food security and sustainable development. His research and advocacy for advanced agricultural practices, coupled with his commitment to alleviating hunger and poverty, have left an indelible mark on the nation's progress

The Bharat Ratna is a well-deserved acknowledgment of Dr. M.S. Swaminathan's lifetime dedication to scientific research and his unwavering commitment to improving the lives of farmers and ensuring food security for the nation. His vision and leadership continue to inspire the next generation of scientists and policymakers in the quest for sustainable and inclusive agricultural practices

Dr. Deepak Kumar
FOUNDER & EDITOR


EXPLORING
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Role of Gibberellic Acid in Fruit Set, Yield and Quality Improvement of Custard Apple (*Annona squamosa* L.)

ARTICLE ID: 0075

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Custard apple (*Annona squamosa* L.) belonging to the Annonaceae family, is believed to be originated in tropical America. It is popularly known as sugar apple (due to its pulp that's sweet and similar to the consistency of custard) or soursop (due to its slightly acidic taste when ripe). This fruit looks nutritious and remarkably important candidate for good health management. It contains 73.50% moisture, 23.90% carbohydrates, 1.60% protein, 1.00% iron, 0.30% fat, 0.40% phosphorous and 0.20% calcium. It is also preferred as high calorie fruit (105/100g) (Bal, 1997). It is an aggregate fruit that grows from a single flower with numerous pistils, each with one carpel. Each pistil gives rise to a fruitlet. The fruitlets are referred to collectively as an aggregate or an etaerio (Fig 1 is showing Arka Sahan, a popular variety of custard apple). Fruits are the true representatives of matured polycarpellary apocarpous gynoecium.

Fig 1: Custard apple variety "Arka Sahan", developed from IIHR, Bangalore

Custard apple derivatives offer medicinal advantages. The leaves having significant therapeutic value are amply used to treat several diseases, ulcers and grain pests, while the root is a powerful purgative. Furthermore, custard apple seed oil and seed extract having insecticidal properties are significantly used in insect pest control. Custard apple extracts have also been reported to show antioxidative, anti-inflammatory, and analgesic properties (Chavan *et al.*, 2010).

In spite of having endeavoring potential in horticulture as well as medicinal aspects, farming of custard apple faces severe yield issues due to faulty fruit set. Overall productions get down massively because of improper fertilization. In this scenario, exogenous application of gibberellic acid has been reported beneficial for enhancing the yield and quality of custard apple (Hayes, 1957).

1. Mode of Action of Gibberellic Acid

Gibberellic acids (GA_3) are naturally occurring substances which tend to control several metabolic processes in the plant. They play significant role in enhancement of fruit development, quality and production. Gender expression and the delaying of senescence in leaves and fruit are also elicited by GAs.

In many dwarf types, GA_3 seems to work around the genetic constraints. Gibberellins cause the seeds of plants that need exposure to cold or light to germinate to emerge from dormancy, which is a condition of limited growth and development. In some cases, seeds require water to start germination before they begin to grow. Water infiltration activates gibberellins, which eventually ennoble α-amylase, an enzyme that converts starches into simple sugars (Fig 2). Gibberellins encourage cell elongation in immature roots during germination. In contrary, abscisic acid, a hormone that suppresses gibberellin activity, prevents germination in this route when water is not present.

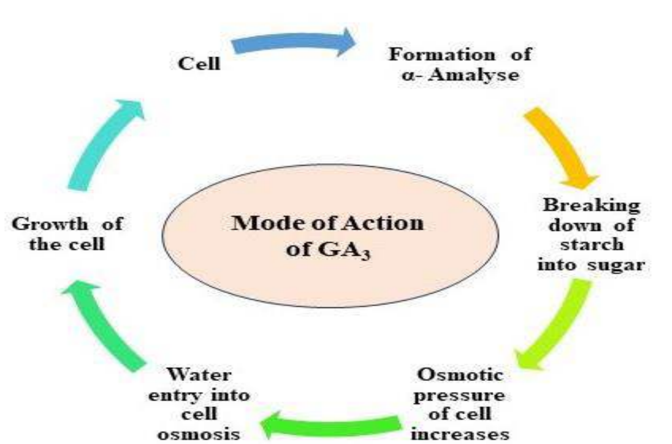

Fig 2: Mode of Action of Gibberellic Acid

Gibberellins and abscisic acid therefore work counter to one another to control the germination response.

2. Effects of GA_3 Application on Fruit Quality in Custard Apple

GA_3 remarkably improves the fruit set, fruit retention, fruit weight, pulp: seed ratio, pulp percentage, fruit diameter and length, leading to fruit yield enhancement.

(a) Fruit Set

The fruit set is derived from the amount of total flower that was turned into a well-formed, healthy fruit, and gibberellic acid improves the fruit set, helping to enhance the yield and quality of fruits. After successful pollination and fertilization, the ovary of the flower is developed into fruit, resulting increasing the fruit set. Gibberellic acid successfully replaces the fertilization process in flowers and induces parthenocarpy in fruit crops.

(b) Flower induction and inhibition

Gibberellic acid possesses vital importance in flower induction and blooming inhibition. GA_3 hinders the production of flowers as long as the sepals have not formed. However, during vernalization, gibberellic acid serves as a florigen and mostly responsible for inducing flowering in fruit crops, despite the fact that the inhibitory impact of gibberellins is more noticeable than flower induction. GA_3 have the ability to substitute for the environmental factors that favor flowering induction, and they are mostly utilized for initiating flowering in long-day plants (King *et al.*, 2006).

(c) Fruit length and diameter

Gibberellic acid enhances fruit size due to cell division, cell elongation, and expansion of vesicles, and loosened the cell wall resulting from increased plasticity. It was found that the increase in fruit size in custard apples in response to growth regulator application including which gibberellic acid may reflect their potential to drive glucose translocation to the fruit in conjunction with their influence on enhancing cell wall flexibility and fruit length.

(d) Fruit weight

Fruit weight is an important yield-contributing feature that would increasing the yield per unit area and consequently increase profit. So, the fruit weight enhancing due to the external supply of gibberellic acid directly responsible for the fruit weight as it promotes cell division and cell elongation. The foliar application of growth regulators encourages cell proliferation and enlargement, encourages active polar transport, and increases the storage of food resources like carbohydrates and water in enlarged cells.

(e) Fruit yield

Fruit yield generally depends on the weight of the fruit and the number of fruits per tree. This is called overall fruit development, which means the process of the cells enlarging to produce a larger fruit once the fruit has been successfully hung on the tree. Gibberellins work best when applied during the phases of fruit development because they boost fruit size and yield. Applying gibberellins 20 to 30 days before harvest results in larger, firmer cherry fruits because gibberellic acid stimulates cell enlargement and cell division, increasing the quantity and size of fruits, resulting in increased fruit production and fruit weight (Looney and Lidster, 1980).

(f) Pulp: seed ratio

GA_3 helps to increase the pulp ratio due to cell division and cell elongation and it will also play an important role in reducing seed number in the fruit when applied after fertilization.

3. Effects of GA_3 Application on Biochemical Aspects in Custard Apple

Gibberellic acid stimulates the flowering, development, and growth of the fruit, resulting in extreme fruit quality. It improves several biochemical parameters, *i.e.,* total soluble solids (˚B), reducing sugar, titratable acidity, total sugar, ascorbic acid, *etc*. GA_3 increases in total soluble solid (˚B) may be due to the quick metabolic conversion of pectin and starch into soluble molecules and the speedy translocation of sugars from leaves to fruits. Furthermore, it boosts up the transfer of metabolites from other areas of the plant to growing fruits, resulting the activity of enzymes like amylases, which hydrolyze complex polysaccharides into simple sugars, may be increased. Eventually, cellular levels of ascorbic acid get increased throughout the growth and development of fruits. In addition, The gibberellic acid that positive influence on custard apple acidity. The acidity decreases with the increasing in the concentration gibberellic acid. This may be due to metabolic alterations that include the rapid conversion of organic acids into sugars and their derivatives through processes involving the reversal of the glycolytic pathway or respiration.

Conclusion

Custard apple is a delicious fruit, used for processing and medicinal purpose but the farming of custard apple faces severe yield issues due to faulty fruit set. Overall productions get down massively because of improper fertilization. In this scenario, exogenous application of gibberellic acid is believed to be beneficial for enhancing the yield and quality of custard apple and helps to better income for farmers and maintaining the living of standard.

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Breeding for Disease Resistance in Pigeon Pea

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Pigeon pea [*Cajanus cajan* (L) Millsp.] is a versatile food legume, serving as a lifeline to resource poor farmers in tropical and subtropical regions of Asia, Africa and Latin America. It belongs to the family 'Fabaceae' and is also known as 'Arhar' or 'Tur', generally used in preparing '*Dal'* which is rich in protein (24-25%) and minerals and eaten by majority of Indian vegetarian population. Pigeon pea is diploid with 2n=2x=22 chromosomes. Pigeon pea is known for both a food crop (dried peas, flour or green vegetable peas) and a forage/cover crop. In combination with cereals, pigeon pea makes a well-balanced human food.

Pigeon pea is very drought resistant, so can be grown in areas with less than 650 mm annual rainfall. It contains 22.3% protein, 1.7% fat, 3.5% minerals, 1.5% fibre, 57.6gm carbohydrate, 73 mg Ca and 0.5 mg Fe, respectively as per 100 g of pigeon pea. It is contain vitamins and minerals such as thiamine, riboflavin, niacin, vitamin B-6, vitamin A along with phosphorus, potassium, zinc and sodium. In India, pigeon pea occupies an area of 4.82 million ha with the production of 3.88 million tones and 804 kg/ha productivity.

In India pigeon pea is suffered by three major disease including wilt (*Fusarium udum*), Phytophthora blight (*Phytophthora drechsleri* f.sp cajani) and sterility mosaic disease. Therefore, it is the need to release disease resistant hybrid of pigeon pea through breeding programme in order to stabilize the production for which identification of reliable disease resistant donors are important.

1) Fusarium Wilt

Symptoms

- First indications of wilt - Patches of dead plants in the field at flowering or podding.

- ❖ Partial wilting - definite indication of Fusarium wilt and distinguishes this disease from termite damage & drought.
- ❖ Browning or blackening of the xylem.

2) Sterility Mosaic Disease

Symptoms

- ❖ In the field, the disease can be easily identified by patches of bushy and show a light and dark green mosaic pattern.
- ❖ When infection occurs at 45 days after emergence or later, only some parts of the plant may show disease symptoms, while the remaining parts appear normal.

3) Phytophthora Blight

Symptoms

- ❖ Phytophthora blight resembles damping off disease as the seedlings die suddenly.
- ❖ Infected plant has water-soaked lesions on their leaves.
- ❖ Brown to black, slightly sunken lesions on their stems and petioles.
- ❖ Lesions girdle on the main stems or branches which break at this point.

Why Resistant Breeding?

- ➢ Cost effective
- ➢ To prevent yield losses
- ➢ Easily adaptable
- ➢ Eco-friendly for agriculture

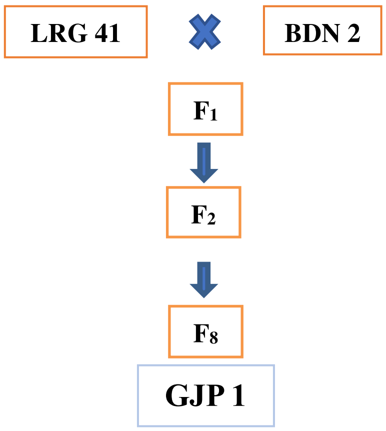
Breeding Methods for Disease Resistance

- ➢ Plant Introduction
- ➢ Selection
- ➢ Hybridization
- ➢ Mutation breeding

Plant introduction is a process of introducing plants (a genotype or a group of genotypes) from their own environment to a new environment. Disease resistant varieties from other places within the countries or even between two countries can be exchanged. ICP 9145 pigeon pea wilt resistant variety introduced in Malawi from other country. ICP 00040 wilt resistant and ICP 8861 phytophthora blight resistant variety introduced in Tanzania from other country.

Isolation of plants having the desirable combination of characters based on their phenotype and growing their progeny is called selection. *C. acutifolius*, *C. albicans*, *C. lineatus* and *C. crassus*, species are selected from different locations which resistance against sterility mosaic disease. Different varieties of pigeon pea PA 291, VL Arhar 1, TS 3R, RGT 1 and TDRG 4 are released through pure line selection method which are effective against different pigeon pea disease.

Hybridization is used when resistant genes are available either in the germplasm or in wild species of crop plants. After hybridization, the hybrid material is handled either by pedigree method or backcross method.



Average yield is 2115 kg/ha, Protein contain 19.51%, Resistance for wilt, SMD & blight disease.

backcross method is useful to transfer disease resistance from one variety to another but it is also useful for transfer of other characteristics.

Mutation breeding is the process of exposing seeds to chemical, radiation or enzymes in order to generate mutants with desirable traits to be bred with other cultivars. Trombay Vishakha 1, CO-3, CO-5, TAT-5 and TAT-10 are pigeon pea disease resistance varieties developed through mutation breeding in India.

Looking to the importance of pigeon pea as a source of protein, disease resistance is primary importance for crop improvement programme. It is governed by particular dominant or recessive genes. By combining conventional breeding approaches, we can develop high yielding disease resistance varieties.

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Trichoderma a Boon for Farmers

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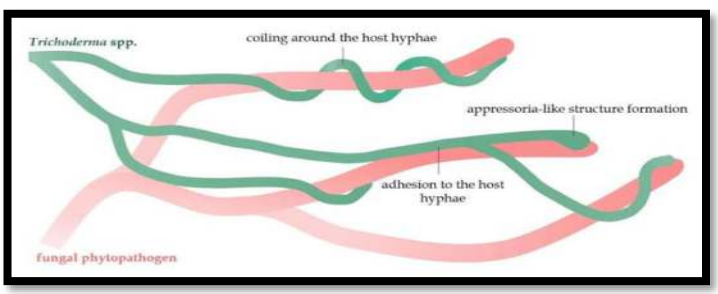
Why we use Trichoderma in agriculture?

Trichoderma is used in agriculture for several reasons:

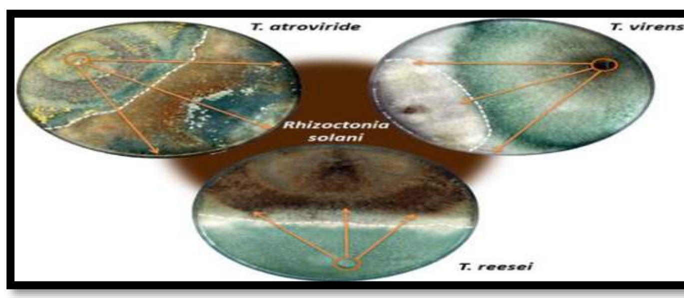
Biological Control: Trichoderma species are natural antagonists of various plant pathogens, such as fungi that cause root rot or damping-off diseases. When applied to the soil or plant roots, they can suppress the growth of these harmful pathogens, reducing the need for chemical pesticides.



Enhancing Nutrient Uptake: Trichoderma can promote plant growth by improving nutrient uptake. They produce enzymes that help solubilize essential nutrients like phosphorus and make them more available to plants.

Stress Resistance: Trichoderma can enhance a plant's resistance to environmental stressors, including drought and salinity. This can lead to better crop yields, especially in challenging growing conditions.

Biological Decomposition: Some Trichoderma species can break down organic matter, aiding in the decomposition of crop residues and other organic materials. This can improve soil health and nutrient cycling.



Root Growth: Trichoderma can stimulate root development and increase root branching, which can result in stronger and healthier plants with improved access to water and nutrients.

Sustainable Farming: The use of Trichoderma in agriculture aligns with sustainable farming practices as it reduces the reliance on chemical pesticides and fertilizers, thus promoting environmentally friendly and organic farming methods. Overall, Trichoderma plays a valuable role in promoting plant health and improving crop yields while reducing the environmental impact of agriculture.

How Trichoderma fungi work?

Trichoderma fungi work through various mechanisms to benefit plants and suppress plant pathogens. Here's how they function:

Antagonism: Trichoderma species are natural antagonists to many plant-pathogenic fungi. They produce antifungal compounds and enzymes that can directly inhibit the growth and development of these harmful pathogens.

Competition: Trichoderma competes with pathogenic fungi for space and nutrients in the rhizosphere (the area around plant roots). Their rapid growth and colonization of the root zone can crowd out pathogenic fungi, limiting their ability to establish and cause disease.

Induced Systemic Resistance (ISR): Trichoderma can trigger a plant's natural defense mechanisms. When in close proximity to plant roots, they can induce systemic resistance in the host plant. This means the plant becomes more resistant to various diseases and stressors, even those unrelated to the specific pathogen that Trichoderma is suppressing.

Production of Enzymes: Trichoderma fungi produce enzymes, such as cellulases and chitinases. These enzymes can degrade the cell walls of pathogenic fungi, making them more susceptible to attack by Trichoderma or other biocontrol agents.

Nutrient Solubilization: Trichoderma can solubilize essential nutrients like phosphorus and iron, making them more available to the plant. This enhances the plant's nutrient uptake and overall health. Enhanced Root Growth: Trichoderma can stimulate root growth and branching. Stronger and healthier root systems provide plants with better access to water and nutrients, which can improve their overall growth and resilience. In essence, Trichoderma fungi act as beneficial microorganisms in the rhizosphere, promoting plant health and suppressing plant diseases through a combination of direct and indirect mechanisms. This makes them a valuable tool in sustainable agriculture and biological pest and disease management.

Preparation procedure?

Preparing Trichoderma for use in agriculture is relatively straightforward and can be adapted for rural farmers. Here's a simple procedure:

Materials Needed

Trichoderma Culture: Obtain a Trichoderma culture from a reliable source, such as an agricultural extension office, research institution, or a trusted supplier.

Substrate: You'll need a suitable substrate for growing Trichoderma. Common options include rice, wheat, or maize grains. Choose a substrate that is readily available in your area.

Water: Clean, chlorine-free water is essential for the process.

Procedure

Sterilize Equipment: Thoroughly clean and sterilize all equipment that will come in contact with the Trichoderma culture. This includes containers, measuring utensils, and any tools you'll use.

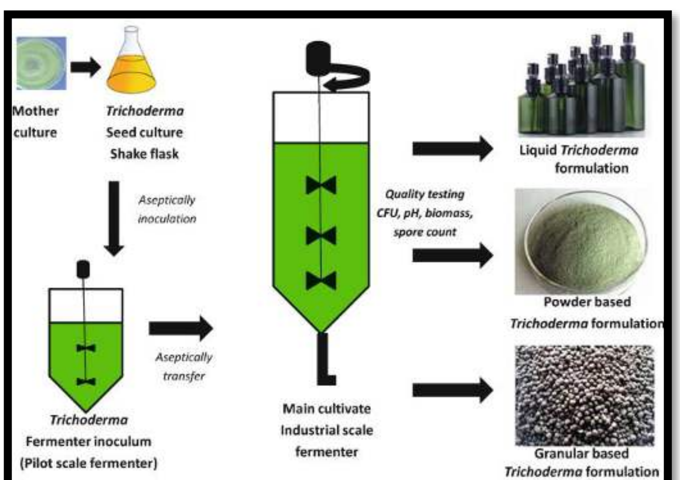
Prepare Substrate: Wash and rinse the chosen substrate (e.g., rice grains) to remove any impurities. Then, cook or steam the substrate until it's well-cooked but not mushy. Let it cool to room temperature.

Inoculate Substrate: Mix the cooled substrate with the Trichoderma culture. Use a clean, sterilized spoon or spatula. The amount of Trichoderma culture to use depends on the instructions provided with the culture but generally ranges from 1-5 % of the substrate weight.

Incubation: Transfer the substrate-Trichoderma mixture into clean, sterile containers. Seal the containers with lids or plastic wrap with small holes for air exchange. Place the containers in a dark, warm (25-30°C or 77-86°F), and well-ventilated area.

Monitor Growth: Check the containers regularly for Trichoderma growth. It should appear as white or greenish mold-like growth on the substrate. This can take 7-10 days or longer, depending on temperature and humidity.

Harvest: Once the Trichoderma has fully colonized the substrate, it's ready for use. The culture should have a pleasant, earthy smell.



Product development process of different formulation of *Trichoderma* sp. using submerged batch fermentation

Application:

To use the Trichoderma culture in your fields:

Dilution: Mix the Trichoderma culture with water to create a suspension. The recommended dilution rate depends on the specific application and the crops you are growing. Consult with local agricultural experts for guidance on the appropriate dilution ratio.

Application Method: You can apply the Trichoderma suspension as a soil drench, seed treatment, or foliar spray, depending on your crop and the specific disease or pest issue you are addressing. Remember to maintain cleanliness and sterility throughout the process to prevent contamination. Always follow local agricultural recommendations and consult with agricultural extension services or experts for specific guidance on Trichoderma use in your region and crop.

How Trichoderma controls plant pathogens?

Trichoderma controls plant pathogens through several mechanisms, making it an effective biocontrol agent: Competition for Resources: Trichoderma rapidly colonizes the rhizosphere (the area around plant roots) and competes with plant pathogens for space and nutrients. This competition can limit the establishment and growth of pathogenic fungi. Antagonism: Trichoderma produces secondary metabolites, such as antibiotics and enzymes that have antifungal properties. These compounds can directly inhibit the growth and development of pathogenic fungi by disrupting their cell walls or interfering with their metabolism. Mycoparasitism: Some Trichoderma species are mycoparasites, which means they can parasitize and kill other fungi, including plant pathogens. They do this by attaching to the pathogen's mycelium (the fungal equivalent of roots) and then penetrating and destroying the pathogen's cells.

Induced Systemic Resistance (ISR): Trichoderma can trigger a plant's own defense mechanisms. When it colonizes the root zone, it induces systemic resistance in the host plant. This means that the plant becomes more resistant to various diseases, even those unrelated to the specific pathogen that Trichoderma is suppressing.

Enzyme Production: Trichoderma produces enzymes, such as chitinases and cellulases; hat can break down the cell walls of pathogenic fungi. By degrading these walls, they make it easier for other biocontrol agents or the plant itself to attack and control the pathogen.

Nutrient Competition: Trichoderma can also outcompete pathogens for essential nutrients. By solubilizing nutrients like phosphorus and iron, Trichoderma makes them more available to the plant, which can boost the plant's overall health and competitiveness against pathogens.

Biofilm Formation: Trichoderma can form biofilms on plant roots, which can act as a protective barrier against pathogenic fungi. These biofilms can physically prevent pathogens from establishing themselves on the root surface. In summary, Trichoderma employs a combination of direct and indirect mechanisms to control plant pathogens. It competes for resources, produces antifungal compounds, parasitizes other fungi, induces plant defenses, and enhances nutrient availability, all of which contribute to its effectiveness as a biological control agent in agriculture.

How Trichoderma can be a blessing for farmers?

Trichoderma can be a blessing for farmers in several ways:

Natural Pest Control: Trichoderma acts as a natural biocontrol agent against various plant pathogens. It helps reduce the need for chemical pesticides, promoting environmentally friendly and sustainable farming improve the sustainability of farming practices underscores its importance as a blessing for farmers worldwide.

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Mastering Mustard Health: A Guide to Diseases and Effective Management

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The main edible oilseed brassica crop in India, Mustard *(Brassica juncea*), is widely produced traditionally in the eastern, northern, and northwestern states of the country as an intercrop (or mixed crop) as well as a pure crop in marginal and sub-marginal soils. The main cause of the mustard's luxuriant development and productivity in these states is the winter months. Mustard is planted solely as a mixed crop for seed used as a condiment in the Central and Southern states due to their comparatively warmer winter environment. Mustard productivity is lowered by a number of biotic and abiotic factors. There are five major abiotic constraints: drought, salt, heat, frost, and heavy metals stresses. Additionally, biotic stresses such as Alternaria blight, white rust, downy mildew, powdery mildew, and Sclerotinia stem rot are also considered destructive to mustard crop production.There are many fungi that cause yield loss in plants at every stage of growth from seedlings to harvest.Among several diseases, four diseases viz; Alternaria blight (Alternaria brassicae), white rust+downy mildew complex (Albugo candida + Hyaloperonospora parasitica), Sclerotinia stem rot (Sclerotinia sclerotiorum) and powdery mildew (Erysiphe cruciferarum) are of great economic importance.

Alternaria Leaf Spot / Blight: *Alternaria brassicae and Alternaria brassicola.*

Symptoms

Alternaria brassicae creates light grey spots, while Alternaria brassicola develops huge, black, sooty velour patches. Target effects are the symptoms that both viruses produce in concentric rings. It is possible to see circular, concentric rings inside the black or brown colored patches. These lesions spread quickly to other plant parts, including stems and siliques.Leaf blight is frequently caused by the circular spots aggregating to form enormous patches .Severe infection manifests as seedlings damping down and rotting and withering at the foot and root.This infection not only damages fresh crops but also has the capability of damaging any stored crops. As a result of left-over infected crops on the ground after harvest, the majority of infections occur. Additionally, this phytopathogen can be found dormant on perennial plants, vulnerable weeds, and crop debris.

Management

To control this disease, a combination of chemical protection and agricultural management techniques is required.

Among the agricultural methods are:

- Use only certified, hygienic, and clean seeds.
- Plant the seeds at the right moment.
- It is important to keep the plants nourished ensuring that the land is completely cleared of any remaining debris and contaminated weed.
- Field sanitation should be conducted properly.
- It is best to avoid irrigation during the stages of pod production and flowering.
- It is not advisable to rotate crops when growing cruciferous vegetables. (Vegetables of the family Brassicaceae, including cauliflower, cabbage, kale, garden cress, bok choy, broccoli, Brussels sprouts, mustard plant, and other related green leafy vegetables, are considered cruciferous vegetables.)

Chemical Protection: Treat seeds with 2.5 grams of Mancozeb per kilogram of seed. Spray the plant with 2.5 grams of Mancozeb or Zineb per liter of water every 15 days.

White Rust: *Albugo candida*

Symptoms

White rust is also called white blisters or stagheads. In this disease, both local and systemic infections occur. In cases of local infection, white or yellow pustules appear on the underside of leaves, and they later coalesce into larger patches. Whereas, malformations and distortions of floral parts are caused by systemic infection causing hypertrophy and hyperplasia. Inflorescences are completely replaced by a swollen sterile structure known as a stag head.Pathogens are mainly transmitted through contaminated seeds and soil. A cool and humid climate (12-14°C temperature & 60-80% relative humidity) makes this disease more likely to develop.

Management

Management practices to combat this disease include using healthy, clean, and certified seeds, collecting and disposing of infected plant debris, following a long crop rotation with non-host crops, and seeding early in the season. Dressing the seed with Metalaxyl (Apron 35SD) @6g/kg followed by a single spray with Metalaxyl 8% + Mancozeb 64% WP @1000g in 400 liters of water/acre can also be practiced to fight this disease.

Downy Mildew: *Peronospora parasitica*

Symptoms

All aerial components exhibit the symptoms, although leaves and inflorescences exhibit the most noticeable ones. On the lower surface of the leaves, an erratic whitish, and grayish necrotic patch develops.The most noticeable sign is the creation of a stag head, since the infection of the inflorescence results in the peduncle or inflorescence being larger. The diseased inflorescence does not generate any seeds or siliqua. In this instance, the fungus is an obligatory parasite that reproduces by producing oospores on its host plants and inside the tissues of its hosts.

Management

Practices including gathering and destroying diseased plant waste, rotating crops with non-host crops, and sowing seeds early can help control the disease to some extent. Chemical management of this illness can involve treating seeds with Metalaxyl (Apron 35SD) at a rate of 6g/kg, and then spraying with Metalaxyl (Ridomyl MZ) at a rate of 0.2%.

Sclerotinia Stem Rot: *Sclerotinia sclerotiorum*

Symptoms

Sclerotinia stem rot is also referred to as white blight, stem disease, or watery soft rot. The pathogen is necrotrophic and globally distributed. Infections are caused by airborne spores or sclerotia. In the soil, sclerotia are spores that can survive for many years as dormant spores. Germination of the spores and infection are enhanced by moist, humid conditions. Mycelium is formed by the germination of sclerotia in soil, which then infects the plants. Two to three weeks after infection, the disease symptoms can be seen. On branches, stems, and pods, the pathogen causes light brown faded patches. The patches gradually become grayish-white as they expand. The infected stems split and open exposing black hard bodies called sclerotia. This form is the resting form of the fungus.

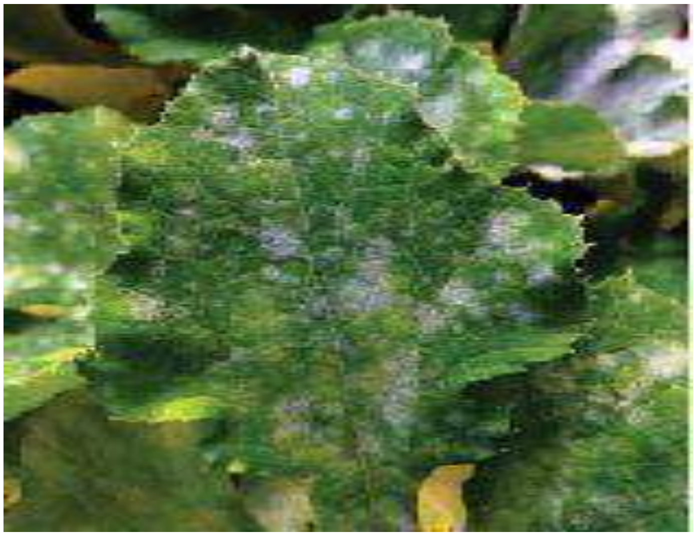
Management

Good agricultural practices such as sowing certified healthy disease-free seeds, and crop rotation can help prevent the occurrence of this disease. Making sure that the field is sanitized properly and the infected left over debris should be removed from the field before sowing.

Powdery Mildew: *Erysiphe cruciferarum*

Symptoms

Every section of the plant above ground is impacted by the illness. The leaf surface develops a powdery white coating on both sides. As a result, the leaf becomes discolored or may even drop off too soon. A plant's leaves, stems, and siliques are impacted when the fungus thrives in the surrounding environment. The disease-affected siliques yield shriveled seeds.Due to its ectophytic nature, the fungus invades the epidermal cells by sending haustoria throughout the leaf's surface. Conidia carried by the wind disperse the illness. This illness thrives in dry climates and becomes more severe when there is flooding.



Management

Agricultural practices like collection and destroying of infected plant debris is helpful in management of this disease. For chemical control of this disease, spray the crop with wettable sulphur@0.2% or Dinocap@0.1% or tridemorph@0.1%.

Conclusion

As we've seen, mustard is a crop that is grown during the winter and can combat certain illnesses of the foliage. The foundation of integrated pest management, sustainable agriculture, which is focused on the environment and public health, is the use of conservation and identification of natural enemies as well as environmentally benign disease management techniques that employ a minimum amount of dangerous synthetic chemicals. It is run using environmentally friendly, mechanically, culturally, and plant-protecting sustainable approaches.

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Impact of Global Trade and Travel on Plant Disease Dynamics

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In an era characterized by unprecedented global connectivity, the intricate interplay between global trade, extensive travel networks, and the dynamics of plant diseases has become increasingly apparent and impactful. The movement of goods, people, and commodities across borders has created a complex web of interactions that significantly influence the spread, emergence, and management of plant diseases worldwide. As international trade and travel continue to expand, the dynamics of plant pathogens undergo continuous transformation, presenting both challenges and opportunities for agricultural systems, environmental sustainability, and global food security. The impact of global trade and travel on plant disease dynamics transcends geographical boundaries and affects various facets of agricultural production and ecosystem health. Trade routes serve as conduits for the inadvertent introduction and dissemination of plant pathogens into new territories, often facilitating the establishment of invasive species and the emergence of novel disease complexes. Moreover, the movement of infected plant material, agricultural products, and vectors across regions can accelerate the spread of pathogens, leading to the escalation of disease outbreaks and the erosion of crop yields and biodiversity.

Pathways of Pathogen Dissemination

The movement of plant pathogens through global trade and travel occurs via various pathways, including:

- **Commodity Trade:** Plant products such as seeds, cuttings, and produce serve as vectors for the introduction and spread of pathogens. Infected plant materials can harbor pathogens, which may remain dormant during transport and become established in new environments upon arrival.
- **International Travel:** Human-mediated transport, including tourism and immigration, can inadvertently introduce pathogens to new regions. Infected plants, soil, and contaminated equipment carried by travelers serve as potential sources of pathogen introduction.
- **Global Transport Networks:** Shipping routes, air traffic, and land transportation networks facilitate the rapid spread of pathogens across continents.

Ports, airports, and transportation hubs act as hotspots for pathogen transmission, posing challenges for quarantine and disease management efforts.

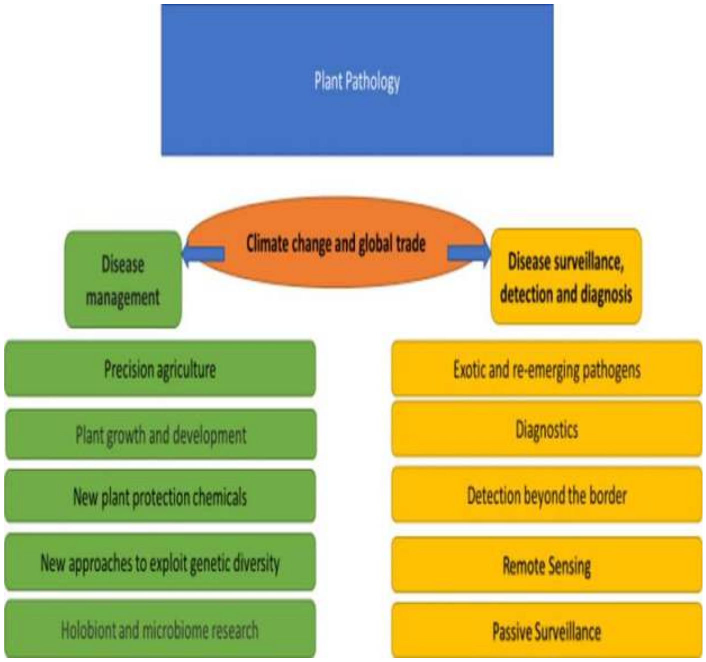
Factors Contributing to Disease Emergence

Several factors contribute to the emergence and spread of plant diseases in a globalized world:

- **Climate Change:** Shifts in temperature, precipitation patterns, and humidity create favorable conditions for the establishment and spread of pathogens in new geographic areas. Climate change can alter host-pathogen interactions, disrupt natural ecosystems, and increase the frequency of disease outbreaks.
- **Globalization of Agriculture:** Intensive agricultural practices, monoculture cropping systems, and the widespread adoption of high-yielding varieties create conducive environments for pathogen proliferation and spread. Agricultural intensification amplifies disease risks and reduces genetic diversity, compromising plant resilience to emerging threats.
- **Invasive Species:** Invasive plants, insects, and other pests serve as vectors for introducing novel pathogens to new environments. Lack of natural predators and ecological barriers can facilitate the rapid spread and establishment of invasive species, exacerbating plant health risks.

International Collaborations and Phytosanitary Measures

International collaborations and phytosanitary measures play a critical role in mitigating the risks associated with global trade and travel:



- **Phytosanitary Regulations:** National and international regulations govern the movement of plant materials to prevent the introduction and spread of pests and diseases. Phytosanitary certificates, quarantine inspections, and pest risk assessments help identify and mitigate potential biosecurity threats.
- **Early Detection and Rapid Response:** Surveillance networks, diagnostic laboratories, and early warning systems enable timely detection and containment of emerging plant diseases. International cooperation and information sharing enhance the capacity to respond effectively to transboundary threats.
- **Capacity Building and Technology Transfer:** Capacity-building initiatives, training programs, and technology transfer promote knowledge exchange and best practices in plant health management. Collaborative research projects and public-private partnerships foster innovation and resilience in agricultural systems.

Conclusion

Global trade and travel have reshaped the dynamics of plant diseases, presenting challenges and opportunities for agricultural systems worldwide. By strengthening international collaborations, enhancing phytosanitary measures, and adopting sustainable agricultural practices, stakeholders can mitigate the risks associated with global trade and travel and promote resilient and inclusive food systems. This highlights the interconnected nature of global trade, travel, and plant health, emphasizing the need for coordinated efforts to address emerging threats and promote sustainable agriculture in a changing world.

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Significance of Biofortification in Horticultural Crops

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Micronutrient malnutrition is known to affect more than half of the world's population and considered to be among the most serious global challenges to humankind. Modern plant breeding has been historically oriented toward achieving high agronomic yields rather than nutritional quality, and other efforts related to alleviating the problem have been primarily through industrial fortification or pharmaceutical supplementation. Micronutrient malnutrition or the hidden hunger is very common among women and preschool children caused mainly by low dietary intake of micronutrients, especially Zn and Fe. Increasing population, inadequate food and nutrition, hunger, malnourishment of vitamins and micronutrients etc. are the biggest challenges to address most of the nations across the world. Vitamin A deficiency (VAD) predominant in developing countries among children and women which leads to >600,000 deaths each year globally among children <5 year of age. Among the micronutrient malnourishment of population about 60% of iron, 30% of zinc, 30% of iodine and 15% of selenium are predominant. Inadequate availability of these important vitamins and micronutrients resulted in many health and physical disorders in human beings. Traditional agricultural practices can partly enhance the nutritional content in plant foods but biofortification is a practice of nutrient fortification into food crops using agronomic, conventional and transgenic breeding methods to provide a sustainable and long term strategy to address negative impacts of vitamin&nutrient deficiencies. Biofortification works have been practiced in most of the horticultural crops like Banana, Cassava, Beans, Potato, Orange sweet potato (OSP), Cowpea, Pumpkin etc. several conventional and transgenic varieties have been released.

What is Biofortification?

Biofortification is the process of adding nutritional value to the crop.It refers to nutrient enrichment of crops to address the negative economic and health consequences of vitamin and mineral deficiencies in humans.

Need for Biofortification

Vitamin A deficiency (VAD) is an important health concern in developing countries among children and women of childbearing age[**1**] and is estimated to account for >600,000 deaths each year globally among children <5 years of age.According to Government of India statistics provided to the World Health Organization (WHO) 62% [1] of all preschool-age children are VAD. Iron (Fe), zinc (Zn), and selenium (Se) deficiencies are serious public health issues and important soil constraints to crop production, particularly in the developing countries.

Methods of Biofortification

1. Agronomic bio fortification
2. Conventional plant breeding
3. Genetic engineering

Agronomic Biofortification

Application of fertilizers to increase the micronutrients in edible parts. The degree of success in agronomic biofortification is proportional to the mobility of mineral element in the soil as well as in the plant[**2**].Most suitable micronutrients for agronomic bio fortification Zinc, (foliar applications of Znso4),Iodine(Soil application of iodide or iodate), Selenium(as selenate).The application of inorganic Se fertilizers resulted in over 10-fold increase in Se concentrations. Synthetic metal chelators (e.g. EDTA-Fe- and Zn-chelates which were effective in increasing mineral concentration in edible vegetable and fruit tissues) [**3**].Foliar application is the quick and easy method of nutrient application to fortification of micro nutrients (Fe,Zn,cu etc.) in plants. Several studies have found that the mycorrhizal associations increase Fe, Se, Zn and Cu concentrations in crop plants **[4].**AM-fungi increases the uptake and efficiency of micronutrients like Zn, Cu, Fe etc.

Conventional Plant Breeding

Traditional breeding mainly focused on yield attributes and resistance breeding from last four decades and lack of priority on nutritional aspects lead's to decreased amount of nutrient status in the existed varieties. Examples of minerals that their mean concentration in the dry matter has declined in several plant-based foods are Fe, Zn, Cu and Mg [**5**]. Recent progress in conventional plant breeding has given emphasis on fortification of important vitamins, antioxidants and micronutrients.

Genetic Engineering

Lack of sufficient variation among the genotypes for the desired character/trait within the species,or when the crop itself is not suitable for conventional plant breeding (due to lack of sexuality; e.g. banana) then genetic engineering offers a valid alternative for increasing the concentration and bioavailability of micro nutrients in the edible crop tissues.One of the main concerns is these-called 'gene flow' environmental problem, i.e. the concern of transfer of foreign genes to non-target species [**8**].Targets for transgenes include, redistributing micronutrients between tissues, increasing the efficiency of biochemical pathways in edible tissues, or even the reconstruction of selected pathways. Some strategies involved in the removal of 'antinutrients'.Since then, there have been similar successes with other crops, giving us a variety of carotenoid-enriched foods **[9]**

Targeted Horticultural Crops Present

Biofortification works have been practiced in most of the horticultural crops like Banana, Cassava, Beans, Potato, Orange sweet potato (OSP), Cowpea, Pumpkin etc. several conventional and transgenic varieties have been released.

Minerals and Vitamins

Minerals, in the context of the human diet, are inorganic chemical elements (or more properly their dissociated ions) that are required for biological or biochemical processes including

the accumulation of electrolytes. Carbon, hydrogen, nitrogen, and oxygen are excluded from the list as these are found in common organic molecules. There are 16 essential minerals, but

11 of them are required in such small amounts and/or are so abundant in food and drinking water that deficiency arises only in very unusual circumstances. The remaining five are present in limiting amounts in many foods, so a monotonous diet can easily result in deficiency. These minerals are iodine (I), iron (Fe), zinc (Zn), calcium (Ca), and selenium (Se).

Alleviating Hidden Hunger Interventions

The term "hidden hunger" has been used to describe the micronutrient malnutrition inherent

in human diets that are adequate in calories but lack vitamins and/or mineral elements. The diets of a large proportion of the world's population are deficient in Fe, Zn, Ca, Mg, Cu, Se, or I, which affects human health and longevity and therefore national economies. Mineral malnutrition can be addressed by increasing the amount of fish and animal products in diets, mineral supplementation, and food fortification and/or increasing the bioavailability of mineral elements in edible crops.

Promotion of Dietary Diversification

Education is an important element in ensuring that improvements in income result in better

maternal and child health. However, dietary diversification is constrained by resource availability for poor households and seasonal availability of fruits and vegetables. Promotion of home gardens is often touted, but the poor have a high opportunity cost for their labour and often limited land. Increased production of fruits and vegetables for household use reduces resources available for other income-earning or food production activities. This type of effort is also relatively expensive and difficult to sustain on any large scale.

Biofortification: Strategic Advantages

The biofortification strategy seeks to take advantage of the consistent daily consumption of large amounts of food staples by all family members, including women and children who are most at risk for micronutrient malnutrition. As a consequence of the predominance of food staples in the diets of the poor, this strategy implicitly targets low-income households.

Future Challenges

- Promote initiatives supporting large-scale prospective studies on the effects of iron biofortified crops on effectiveness of the adopted biofortification strategy in relieving
- iron deficiency anemia and in improving general health.

- Improve the efficiency with which minerals are mobilized in the soil.
- Improve the efficiency with which minerals are taken up from the soil into the roots of the plant.
- Improve the transport of minerals from the roots to storage tissues, such as grain.
- Increase the capacity of storage tissues to accumulate minerals in a form that does not
- impair plant vegetative growth and development, but remains bioavailable for humans.
- Reduce the level of antinutritional compounds such as phytic acid, which inhibit the absorption of minerals in the gut.

Conclusion

Biofortification in horticultural crops is a transformative approach to enhance the nutritional quality of our food supply. By fortifying essential nutrients in fruits and vegetables, we not only combat malnutrition but also contribute to a healthier, more resilient global population. As we move forward, prioritizing research, investment, and public awareness will be crucial in realizing the full potential of biofortification to create a world where everyone has access to nutritious and wholesome food.

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Unlocking Nature's Potential: Green Synthesized Nanoparticles Paving the Way for Sustainable Agriculture

ARTICLE ID: 0081

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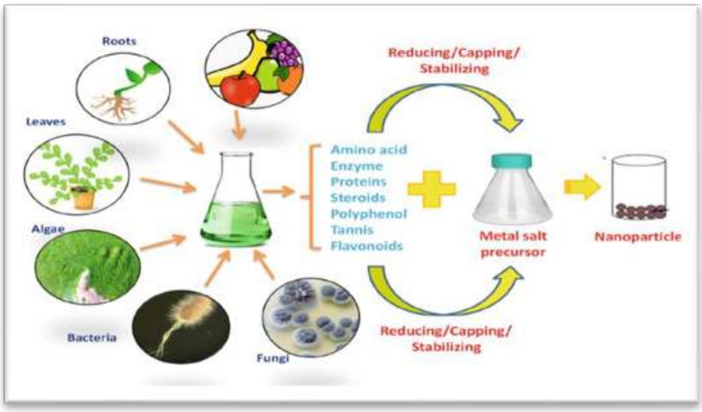
Agriculture, particularly horticultural crops, is a major economic sector involved in the cultivation and distribution of a diverse variety of specialty crops for food, feed, and decorative reasons, and it is today a multitrillion-dollar business globally. Limited resources and a fast-growing human population, which is expected to reach 9.6 trillion people by 2050, drive the industry ahead, requiring the development of highly efficient agriculture while reducing global poverty and hunger (Zul et al., 2019). Since the emergence of agriculture around 10,000 B.C., the large amount of land dedicated to agriculture and animal husbandry has drastically affected the landscapes of Europe and the rest of the globe. This trend is expected to continue, with the Food and Agriculture Organisation of the United Nations (FAO) forecasting a significant rise in global food production in the future years, particularly in developing nations (FAO, 2011). We don't have an infinite amount of time to discuss; we have less than 10 years until 2030 when we should have met the universally agreed-upon, UN-mandated Sustainable Development Goals. What is required today is action and substantial progress toward establishing a shared route and vision for transitioning to a type of sustainable agriculture that benefits human beings, food production, and the environment (Oberč & Arroyo Schnell, 2020)



In recent years, nanotechnology has gained attention as a potential solution to address the sustainability challenges in agriculture. Nanotechnology involves the manipulation of matter at the nanoscale, typically at dimensions less than 100 nanometers. Nanoparticles, due to their small size and large surface area-to-volume ratio, exhibit unique physicochemical properties that differ from their bulk counterparts. These properties make nanoparticles promising candidates for various applications, including agriculture. Nanotechnology in agriculture, often referred to as nanotechnology in agri-food systems or nanobiotechnology, encompasses the use of nanomaterials and nanodevices to enhance agricultural productivity, improve crop protection, and promote sustainable practices. Green synthesized nanoparticles, in particular, have gained attention as a sustainable alternative to conventional nanoparticles due to their eco-friendly synthesis routes and potential environmental benefits(Zul et al., 2019)

Applications of Green Nanoparticles in Sustainable Agriculture

1. Crop Growth Enhancement

Green combined nanoparticles have proved promising results in reinforcing crop development and improving overall plant energy. The singular features of nanoparticles, such as their littleness and extreme surface district, enable effective mineral uptake, improved water memory, and upgraded plant stress tolerance. Few key requests of green nanoparticles in crop growth augmentation contain:

- ❖ Nutrient Delivery: Nanoparticles can be loaded with essential nutrients, such as nitrogen, phosphorus, and micronutrients, and delivered to plants in a controlled manner. This targeted nutrient delivery improves nutrient use efficiency, reduces fertilizer wastage, and enhances plant growth and productivity.
- ❖ Seed Priming: Nanoparticles can be applied during seed priming to enhance germination, seedling vigor, and early plant growth. The nanoparticles facilitate water uptake, protect against pathogens, and provide essential nutrients to the developing seedlings.
- ❖ Foliar Spray: Nanoparticles can be applied as foliar sprays to improve nutrient absorption and enhance photosynthesis. They can also act as carriers for growth-promoting substances, such as plant hormones or beneficial microorganisms, leading to improved plant growth and development (Singh et al., 2021)

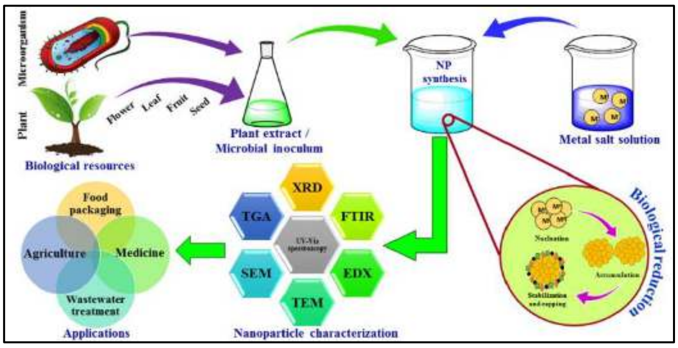


Figure 1: Green synthesis of Nanoparticles and their Application.

2. Nutrient Management

Green nanoparticles offer innovative approaches for efficient nutrient management in sustainable agriculture. They can enhance nutrient availability, reduce nutrient losses, and improve nutrient use efficiency. Some applications of green nanoparticles in nutrient management include:

- ❖ Slow-Release Fertilizers: Nanoparticles can be used as carriers for slow-release fertilizers, allowing controlled nutrient release over an extended period. This approach minimizes nutrient leaching, reduces environmental pollution, and provides a sustained nutrient supply to plants.
- ❖ Nutrient Solubility and Uptake: Nanoparticles can improve the solubility of poorly soluble nutrients and facilitate their uptake by plants. They can also enhance nutrient transport within plant tissues, ensuring effective nutrient distribution to various plant parts.
- ❖ Rhizosphere Interactions: Green nanoparticles can modify the rhizosphere environment, promoting nutrient availability and enhancing nutrient uptake by plants. They can interact with soil particles, organic matter, and root exudates, influencing nutrient cycling and improving nutrient acquisition efficiency (Ditta et al., 2020).

3. Pest and Disease Control

Green synthesized nanoparticles have shown potential in pest and disease control strategies in sustainable agriculture. Their antimicrobial, antifungal, and insecticidal properties can be harnessed to reduce the use of conventional pesticides and mitigate the development of pesticide resistance. Some applications of green nanoparticles in pest and disease control include:

- ❖ Insect Pest Management: Nanoparticles can act as insecticides, repellents, or insect growth regulators, targeting specific pests while minimizing adverse effects on beneficial insects and the environment. They can disrupt insect physiology, affect their behavior, or act as physical barriers to prevent pest infestation.

- ❖ Fungal and Bacterial Ailments: Green nanoparticles can prevent the tumor of fungal and bacterial pathogens and suppress the growth of plant afflictions. They can pierce bacterium containers, obstruct their metabolic processes, and disrupt their container membranes, superior to affliction control.
- ❖ Nanosensors for Disease Detection: Nanoparticles can be functionalized with specific biomolecules or antibodies to detect and identify plant pathogens at an early stage. These nanosensors enable rapid and accurate disease diagnosis, facilitating timely and targeted disease management strategies (Elmer et al., 2018).

4. Soil Remediation

Green nanoparticles offer innovative solutions for soil remediation and environmental sustainability. They can be utilized to mitigate soil pollution, remove contaminants, and improve soil health. Some applications of green nanoparticles in soil remediation include:

- ❖ Heavy Metal Remediation: Nanoparticles can bind to heavy metal ions in soil, immobilizing them and preventing their uptake by plants. They can also facilitate the transformation of toxic metals into less toxic forms, reducing their bioavailability and environmental impact.
- ❖ Organic Pollutant Degradation: Green nanoparticles can catalyze the degradation of organic pollutants, such as pesticides, herbicides, and petroleum derivatives, through advanced oxidation processes. They promote the breakdown of these contaminants into harmless byproducts, reducing soil pollution and improving soil quality.
- ❖ Soil Structure Improvement: Nanoparticles can interact with soil particles and organic matter, improving soil aggregation and stability. They enhance soil water-holding capacity, aeration, and nutrient retention, leading to improved soil fertility and plant growth.

The applications of green nanoparticles in sustainable agriculture are diverse and hold significant potential for addressing various challenges in crop production, nutrient management, pest and disease control, and soil remediation. Continued research and development in this field will contribute to the advancement of sustainable agricultural practices with reduced environmental impact and increased productivity (Manna et al., 2023).

Advantages and Limitations of Green Nanoparticles in Agriculture

Green synthesized nanoparticles offer several advantages for sustainable agriculture. They are produced using eco-friendly methods, utilizing renewable plant materials or bio-waste, thereby reducing the reliance on toxic chemicals. Green nanoparticles also exhibit lower toxicity compared to their chemically synthesized counterparts, reducing potential risks to the environment and human health. Additionally, green synthesized nanoparticles can be easily scaled up for large-scale production, making them practical for agricultural applications. However, the use of nanoparticles in agriculture also presents certain limitations and challenges. One major concern is the potential for nanoparticle release into the environment and their subsequent fate and transport, which requires careful risk assessment and management. Additionally, the long-term impacts of nanoparticles on soil health, microbial communities, and ecosystem functioning need further investigation. Standardization of synthesis methods, characterization techniques, and guidelines for nanoparticle application in agriculture are also essential for safe and sustainable implementation. The literature review highlights the significant role of green synthesized nanoparticles in sustainable agriculture. Green nanoparticles offer potential solutions to enhance crop growth, improve nutrient management, control pests and diseases, and remediate contaminated soils. Their eco-friendly synthesis routes and unique physicochemical properties make them promising tools for achieving sustainable agricultural practices. However, further research is required to better understand the environmental and health implications associated with the use of nanoparticles in agriculture, and to establish guidelines for their safe and responsible implementation in the field (Dashora & Sharma, 2018).

So, as we stand at the crossroads of innovation and sustainability, let us embrace the potential of green synthesized nanoparticles. Together, we can cultivate a future where agriculture thrives in harmony with nature, ushering in a new era of abundance and ecological balance.

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Unlocking Agricultural Potential: Harnessing the Power of Growth Regulators

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Plant growth regulators, once known as "Utteshu Vila" in older literature, have undergone a transformation in terminology, now commonly referred to as "phytohormones." Coined by Thiman in 1948, the term "phytohormones" emphasizes their vital role in stimulating plant growth and development. This article delves into the significance of plant growth regulators, tracing their evolution from traditional understanding to modern scientific insights.

Organic substances which are naturally synthesized in the plant, synthesized in one part and distributed to another part, where in very small quantities they affect the growth and other physiological functions of the plant, are called phytonutrients." However, the term growth regulator is used for chemical substances that act like stimulants, but are synthesized artificially. Different types of plant growth regulators. (1) Auxin (2). Gibberellin (3) Cytokinin (4). Ethylene (5). Abscisic Acid.

1. Auxins

Auxin's discovery traces back to Charles Darwin's observations in 1880, studying canary grass and noting phototropism in the plant's tip. Building on Darwin's work, Boysen-Jensen (1913) and Went (1926) conducted pivotal experiments, culminating in the identification of indole acetic acid (IAA) as the substance responsible for bending responses. IAA synthesis begins with tryptophan, making it a precursor chemical. Produced in regions of active growth, such as developing leaves, embryos, and fruits, auxin exhibits polar movement, primarily downward from the tip. Went's avena-ture test elucidated auxin's influence, as the coleoptile bent away from agar block pieces containing IAA. These discoveries underscore auxin's pivotal role in plant development, influencing growth processes and tropic responses, and paving the way for further understanding of plant hormonal regulation. Auxin's significance extends to agriculture, where it is utilized in plant propagation, root formation, and other growth modulation techniques.

The Role of Auxins

The role of auxin in plant physiology is multifaceted. One of its crucial functions is maintaining apical dominance, wherein it suppresses the growth of buds emerging from leaf axils, ensuring the dominance of the apical bud. Removal of the apical bud triggers growth in the axillary buds. Additionally, auxin plays a pivotal role in cell division and enlargement, particularly in the apical region, by increasing cytoplasm permeability and enhancing cell wall plasticity. This hormone also influences shoot and root growth, promoting shoot growth at higher concentrations and root growth at lower concentrations. Furthermore, auxin facilitates xylem differentiation, aiding in bud grafting in callus and ensuring proper vascular tissue connection for bud growth. It also enhances nucleic acid activity, stimulating RNA synthesis and specific enzyme production, thereby contributing to cell expansion. Ultimately, auxin's regulation of cellular growth, influenced by phytocatalyst levels, is fundamental to overall plant growth and development.. The different types of growth-related movements occurring in plants are as follows:

2. Gibberellins

In 1926, Japanese scientist Kurosawa discovered gibberellin, a substance extracted from the fungus *Gibberella fujikuroi*, which causes "foolish seedling disease" in rice plants. This disease made the plants tall, yellow, and seedless due to the fungus's secretions. Yabuta, Hayashi, and Kanbe were the first to isolate an active substance called gibberellin from this fungus. Later, Yabuta and Sumiki isolated gibberellin A and gibberellin V from fungi. Gibberellin was also found in higher plants, first isolated from *Phaseolus coccineus* by McMillan and Suter in 1958. Gibberellins are made in young leaves, roots, and shoots and move throughout the plant via phloem and xylem.

Role of Gibberellins

Gibberellin, a plant hormone, influences various aspects of plant growth and development. Firstly, it counteracts genetic dwarfism in plants by promoting increased height, particularly in species like pea, broad bean, and *Fasciosus multiflorus*, where mutations inhibit gibberellin synthesis, resulting in small nodes. Secondly, it facilitates the formation of flower stalks and flowering, especially in rosette plants and those requiring cold treatment for flowering. However, it doesn't induce flowering in short-photoperiod plants under inappropriate light conditions. Gibberellin affects the emergence of floral whorls by stimulating cell division and elongation in the sub-head region. Thirdly, gibberellin overcomes light inhibition of stem growth by increasing cell wall flexibility, thus promoting elongation, which is particularly evident in shade-grown plants. Fourthly, it serves as a reliable inducer of parthenocarpy, allowing fruit development without fertilization, unlike auxin. Lastly, gibberellin stimulates the germination process in endotrophic seeds by activating the enzyme amylase, which mobilizes starch stored in the endosperm to support embryo growth.

3. Cytokinins

This is the generic name for substances that stimulate cell division in plants. And growth affects regulatory functions. Cytokinin is also called phytocyanin. Haverlandt (1913) Presented evidence that cell division is facilitated by substances obtained from phloem. Skoog,(1955) demonstrated that when the pith tissues of tobacco were separated from the vascular tissues So its growth took place without cell division. When the vascular tissues were brought back into contact, the marrow tissues Cell division occurred again. This test led to the discovery of cytokinin. Miser and Skoog (1955) described herring sperm-D Isolated a substance from non-serial nucleic acid and named it kinetin. In 1964, Skoog Zivatin was isolated from and after that other cytokinins were isolated.

Role of Cytokinin

Cytokinin and auxin play crucial roles in various aspects of plant growth and development. Firstly, they interact to regulate cell division and differentiation. When both substances are adequately supplied in tissue culture, they promote cell division and the formation of undifferentiated masses known as callus cells. Alterations in the ratio of cytokinin to auxin can lead to the differentiation of callus cells into plant tissues such as stems and leaves. Secondly, cytokinin influences cell and organ enlargement, as observed in experiments with cut cotyledons of various plants. This enlargement occurs through the absorption of water, facilitated by cytokinin-induced conversion of fats into reducing sugars, which are further metabolized into osmotically active sugars. Thirdly, cytokinins affect seed germination, with studies showing enhanced germination rates in lettuce seeds treated with kinetin or other cytokinins compared to seeds grown in darkness or under infrared light, which inhibits germination. Additionally, cytokinin regulates root initiation and growth, with low concentrations promoting root budding and elongation, while high concentrations inhibit root growth in certain plant species like lupine. Lastly, cytokinins play a role in bud development and shoot growth, influencing branching patterns and apical dominance. Application of cytokinin to the apical bud can promote lateral bud growth and branching, altering the plant's overall architecture.

4. Ethylene

This is the only gas nature's catalyst. Gain (1934) proved that ethylene is a natural product of ripening fruits. Evidence of ethylene production has been found in leaves, flowers, seeds and roots.

Role of Ethylene

- **Fruit Ripening:** Fruit ripening involves an active process known as climacteric, marked by increased respiration followed by a decline. It includes hydrolysis of stored substances, pigment changes, altered respiratory rates, fruit softening, flavor development, and other biochemical reactions. Tissue permeability changes, enzyme production like malate synthase, and metabolic shifts contribute to ripening.
- **Seedling Emergence and Growth:** Seedling growth varies in dicotyledonous seeds, with above-ground germination leading to straight stem growth,

while hypogeal germination keeps cotyledons underground. Ethylene regulates growth, promoting straight growth under light. Absence of light causes etiolation, inhibiting arc expansion.

- **Leaf Abscission:** Leaf abscission involves the formation of a parenchyma layer at the petiole base triggered by cell-transforming enzymes, protein synthesis, and increased respiration. Ethylene synthesis induces senescence and enhances separation.

5. Abscisic Acid

In 1961, Liu and Kanous discovered a substance in cotton fruits that induced the separation of debladed petioles, naming it abscisin. However, its structure wasn't fixed. During further research, Ohkuma and colleagues isolated a similar substance from new cotton fruits, termed Abscisin-2nd. By 1965, they proposed its chemical structure. Concurrently, Carnaghavan and colleagues found a substance named dourmin in sycamore leaves, later identified as identical to abscisin. To prevent confusion, the substance was standardized as abscisic acid.

Role of Abscisic Acid

Abscisic acid (ABA) serves various roles in plant physiology. Initially believed to accelerate abscission, it was later found to mildly affect the separation process. ABA's involvement in dormancy, observed in potato tubers and dormant buds, is debated. It inhibits germination enzyme production, preventing vivipary. ABA, along with gibberellins and cytokinins, regulates seed germination by inhibiting specific germination factors. It induces stomatal closure by reducing potassium absorption and cell swelling, releasing malic acid. ABA accumulates in water-deficient plants, closing stomata to aid survival during water stress.

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Transforming Indian Agriculture: Harnessing Drone Technology for Sustainable Farming

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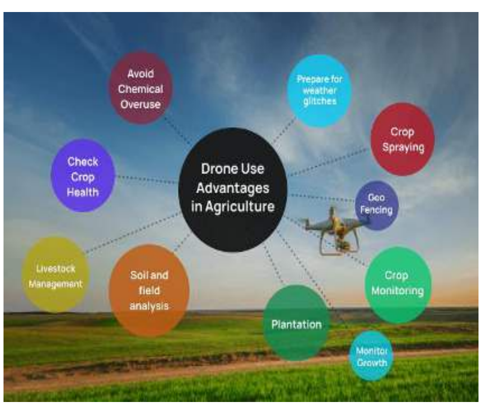
The population is increasing tremendously and with this increase the demand of food. The traditional methods which were used by the farmers were not sufficient enough to fulfil these requirements. Thus, new automated methods (Drone technology) were introduced. These new methods satisfied the food requirements and also provided employment opportunities to billions of people. Drones' technologies save the excess use of water, pesticides, and herbicides, maintains the fertility of the soil, also helps in the efficient use of man power and elevate the productivity and improve the quality. The objective of this paper is to review the usage of Drones in agriculture applications. Based on the literature, we found that a lot of agriculture applications can be done by using Drone. In the methodology, we used a comprehensive review from other researches in this world.

Applications of Drones in Agriculture



There are various applications of drones in agriculture which are briefly discussed below:

Soil and Field Analysis: Drones can be used to mount sensors which are able to analyze the soil conditions, terrain conditions, moisture content, nutrients content and fertility levels of the soil which can be further used for planning the pattern of sowing of different crops, irrigation scheduling as well as for managing fertilizers application considering spatial variability of the crop growth and field conditions.

Planting Crops and Trees: Drones can be used for planting crops which can save labour cost and reduce human drudgery. As there would be no use of tractors for sowing crops in the field, drones can save fuels, reduce the emission of harmful gases formed during fuel exhaustion While operating tractors in the field, and can avoid the compaction of subsoil as well as formation of plough pan which generally forms due to repetitive movement of tractors on soil surface. Drones can be used to plant trees or crops in remote areas by throwing biodegradable seed pods or seed bombs Thus, they can be used for the restoration of degraded lands by planting trees, and also for reforestation as well as afforestation activities.

Crop Monitoring: Drones can be used for monitoring the conditions of crops throughout the crop season so that the need-based and timely action can be taken. The quick and appropriate action can prevent yield loss. This technology will eliminate the need to visually inspecting the crops by the farmers. They can monitor the horticultural crops or other crops present in remote areas like mountainous regions. They can also monitor the tall crops and trees efficiently, which are otherwise challenging to scout physically by farmers.

Nutrient Status and Deficiency Monitoring: Plants need the appropriate levels of nutrients in order to thrive and produce a strong yield. The appropriate levels of nitrogen will ensure strong growth of vegetation and foliage, appropriate levels of phosphorous are required for strong root and stem growth and appropriate levels of potassium are necessary for improving of the resistance to disease and also to ensure a better quality of crop. If soil lacks any of these nutrients, the plant will become stressed and will struggle to thrive. NDVI Index mosaics offer the possibility to identify exactly which areas of the crops are stressed or struggling and to target directly these areas. The NIR/multispectral imagery provided by the UAVs can identify these management zones long before the problem become visible to the naked eye. This means that these management zones can be targeted before crop development and yield is affected.

Diseases Monitoring: Crop diseases can be devastating and classified as fungal, bacterial or viral. Drones equipped with Infrared cameras can see inside plants, giving a clear image of the condition thereof. If a farmer can detect an infection before it spreads, preventative measures can be taken - like removing the plant - before the infection spreads to neighbour plants. Image-based tools can, thus, play an important role in detecting and recognizing plant diseases when human assessment is unsuitable, unreliable, or unavailable, especially with the extended coverage provided by UAVs. RGB and multispectral images have been preferred methods for acquiring information about the studied areas, but hyper spectral and thermal images have also been tested. The latter is employed mostly to detect water stress signs potentially caused by the targeted disease.

Weed Identification: Drones can be used to identify the weeds present in the field. These weeds could be timely rooted out from the field so that they do not compete for resources with the main crop.

Crop Spraying: Drones can be used to spray chemicals like fertilizers, pesticides, etc. based on the spatial variability of the crops and field. The amount of chemicals to be sprayed can be adjusted depending upon the crop conditions, or the degree of severity of the insect-pest attack. In this way, drones pave the pathway to precision agriculture. This ultimately increases the efficiency of the chemicals applied, thereby reducing their adverse impacts on the environment by decreasing the soil and water pollution. Thus, it can lead towards sustainable agriculture. Drones spray chemicals at a faster rate as compared to other methods. It can also result in the saving of the amount of chemicals applied, which can reduce input cost. There is also a problem of imbalance of tractor operated machinery while spraying chemicals over tall crops which may sometimes result in accidents. So, the spraying of chemicals over tall crops can be done easily by drones without any damage.

Geofencing Or Protecting the Field from Animal Damage: The thermal cameras mounted over drones can detect animals or human beings during the night. So, it can be used to protect fields from the damage caused by animals, which are otherwise difficult to detect in the large fields during night time. So, it will work more efficiently than human guards.

Crop Insurance: Drones can be used for precisely estimating and monitoring of the crop failure. So, it can be helpful for the farmers as well as for insurance companies in providing insurance claims based on the degree of damage. This technology has great potential in accurate and effective implementation of crop insurance scheme, namely Pradhan Mantri Fasal Bima Yojana in India without any bias.

Livestock Management: Drones can be used to manage the large herd of livestock. The sensors having high-resolution infrared cameras present over drone can detect the diseased animal swiftly by their heat signatures. The detected diseased animal can then be separated from their fellow animals, and the early treatment can be provided. So, the drone could be used for precision dairy farming.

Conclusion

Drones have great potential to transform Indian agriculture. With the advancement of technology in the future, the production of drones is expected to become economical. The modern youth are not attracted towards farming due to hard work and drudgery involved in it. The implication of drones may fascinate and encourage the youth towards agriculture. Drones provide real time and high-quality aerial imagery compared to satellite imagery over agricultural areas. Also, applications for localizing weeds and diseases, determining soil properties, detecting vegetation differences and the production of an accurate elevation models are currently possible with the help of drones. Drones will enable farmers to know more about their fields. Therefore, farmers will be assisted with producing more food while using fewer chemicals. Nearly all farmers who have made use of drones have achieved some form of benefit. They can make more efficient use of their land, exterminate pests before they destroy entire crops, adjust the soil quality to improve growth in problem areas, improve irrigation to plants suffering from heat stress and track fires before they get out of control. Therefore, drones may become part and parcel of agriculture in the future by helping farmers in managing their fields and resources in a better and sustainable way.

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Integrated Disease Management in Tea Cultivation: Leveraging Beneficial Microorganisms for Sustainable Production

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Tea (*Camellia spp*.) is one of the most economically important plantation crops and the second-largest non-alcoholic beverage in the world next to water being consumed by people in different forms. It is cultivated mainly in Assam, West Bengal covering the regions such as Darjeeling, Dooars, Terai, and South India in about 6.36 lakh hectares with a production of about 1338 million Kg made teas. Darjeeling tea is world famous for its specific aroma and flavor whereas Assam is known for premier CTC teas

Tea Diseases

Tea plantations are subjected to attack by hundreds of fungal pathogens. Majority of these infect plant leaf, stem, and root, which ultimately decreases the quantity and quality of made tea. Several diseases are prevalent in the North, North East, and South India. The thorny blight of stem, charcoal stump rot, brown root rot, and blister blight diseases are more prevalent in Darjeeling. Phytopathogens such as *Fusarium solani*, *Cephaleuros spp*., *Corticium spp*., *Poria hypobrunnea*, *Ustulina zonata*, and *Fomes lamaoensis* are important to cause immense losses in terms of yield and quality.

Chemical fungicides are much more effective, however, there are certain problems associated with their frequent use such as environmental pollution, health hazards, phytotoxicity, development of resistance, resurgence, and residues in made tea and hence; such fungicides are not permitted in organic tea crop production. Under such a perspective, usage of certain fungi, bacteria, and viruses could be safer and ideal components of integrated disease management (IDM) for production sustainability. This review focused on the management of major tea diseases through the application of microorganisms.

Blister blight (Causal organism: *Exobasidium vexans*)

Exobasidium vexans Massee is responsible for this disease and it can be classified systematically under Subdivision –Basidiomycotina, Order – Exobasidiales, and Family – Exobasidiaceae. Blister blight is one of the most economically important foliar diseases that have emerged as a threat to the tea industry affecting its production and quality in terms of export.

- Beneficial microorganisms such as *Trichoderma harzianum, Gliocladium virens*, Serratia marcescens, *Pseudomonas fluorescens*, and *Bacillus subtilis* could effectively manage this disease
- *Pseudomonas fluorescens* increased indole acetic acid production that helped in the development of a good root system. This bacterium produces antibiotics, siderophores, and hydrogen cyanide playing role in biocontrol activities. *T. viride*, *T. harzianum*,
- *B. subtilis*, and actinomycetes are reported as potential microbes for the control of blister blight under field conditions in North East India. B. subtilis is a successful microbial candidate for the management of certain tea diseases. Antagonist Trichoderma is efficient in controlling certain stem as well as soil-borne root diseases. The isolates of actinomycetes showed an encouraging response toward the control of tea plantation diseases. The spray of Ochrobactrum anthropi strain BMO-111 controlled the blister blight and improved the chlorophyll, polyphenols, and catechins content in the pluckable tea shoots

Blister Blight


Black Rot


Leaf Blight


Red Rust Leaf

Black rot (Causal organism: *Corticium theae and Corticium invisum*)

It is caused by fungal phytopathogen *Corticium theae* and *Corticium invisum*. The pathogens infect the older foliage leading to the steady tea bush health wear and tear which ultimately results in crop yield loss. The sclerotia of fungus germinate in March and April and infect the plantation from May to July. The active stage of the phytopathogenic fungus may last up to September in the field. The overwintering of fungal sclerotia takes place in the stem of tea bushes generally in its cracks and crevices during unfavorable conditions. Such sclerotia again germinate with the advent of favorable environmental conditions and start the fresh infection on the tea bushes. Its seasonal incidence and disease progress occur under the existing weather factors of Darjeeling.

- Application of *B. subtilis* was effective against this pathogen during both active and dormant phases. Its repetitive application at fortnightly intervals provided better disease control. The hand plucking of tea leaves helps in reducing the disease incidence.

Leaf blight (Causal organism: *Pestalotiopsis theae*)

Leaf blight of tea is yet another important disease that is classified into two types, namely, brown and gray blight. *Pestalotiopsis theae*, causing gray blight, is a fungal phytopathogen of global occurrence in tea cultivating areas which has endophytic behavior and is responsible for huge crop losses around the globe

- ❖ Trichoderma isolates reduced the growth of *Glomerella cingulata* significantly, and therefore, it is suitable to include in the IDM strategies for controlling brown blight disease

Stem Diseases

Branch canker caused by *P. hypobrunnea* as well as thorny blight incited by *Tunstallia aculeata* is also of economic significance, infecting the tea bushes in plain and hilly regions of tea growing Indian states. Both pathogens enter through cuts that occurred on the bushes due to the commencement of heavy pruning operations and infect the plant. Therefore, to protect from disease, proper care of fresh pruning cuts is of primary significance, it may be achieved through the application of suitable microbes.

- ❖ Immediately after pruning operation, the application of Trichoderma on the pruned cuts is quite effective in managing both diseases. In the case of rejuvenation and medium pruning, its higher concentration is helpful while in the case of light pruning, its lower concentration is applicable. It was noted that the application of the paste of Talc based Trichoderma formulation on pruned cuts and its soil application at 1 kg/bush was found effective in managing stem diseases *T. harzianum* and G. virens were used against collar canker of tea.

Red rust (Causal organism: *Cephaleuros parasiticus* (Stem) and *Cephaleuros mycoides* (Leaf)

Alga, *Cephaleuros parasiticus*, is the primary causative agent of red rust. In general, the disease infects the young stems of tea bushes. Eventually, the symptoms of the disease appear on leaves. It is comparatively more harmful to young tea plants. The pathogen destroys the stem tissues in patches which ultimately turn into dieback. The appearance of variegation with yellow patches on the leaves of the infected branches is the characteristic feature of this disease. Symptoms of the disease appear as small translucent water soaking spots on leaves. On the upper surface, the spot becomes purple-red, then black with a purple margin. On the under surface, it is purple-red becoming gray-brown with the advancement of time. If it attacks the petiole at its junction with the stem, the leaf falls and its sporangia are spread by wind or rain.

- ❖ Species of Azotobacter, Azospirillum, Bacillus, Pseudomonas, Streptomyces, Trichoderma, etc., protected the tea plantation from red rust under field conditions

Conclusion

Tea is one of the most commonly consumed non-alcoholic beverages in the world after water. Its cultivation encounters the challenges of various diseases. Although these diseases could be controlled by various fungicides, from the health point of view, usage of chemical fungicides is not advisable in tea crop production. Under such circumstances, the IDM approach is the best way to have healthy tea production. Disease resistant or tolerant genotypes, the use of beneficial microbes for the management of diseases, are the components of IDM, which is a vital, economic, Eco friendly viable, and long-lasting successful strategy. To find out resistant/ tolerant tea genotypes, the development of a "disease screening nursery" is of prime need for its sustainability. For the biological control of diseases, local strains of beneficial microbes should be explored followed by their evaluation and commercialization. Disease progress depending on weather factors should be undertaken to realize the role of these factors in the initiation and development of economically important diseases.

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Robotics in Horticulture

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A robot is an automated device that mimics human functions, or a machine in human form. A machine perceives the environment, processes sensor data, and replies with computer commands. Labour is a significant cost in horticulture, accounting for roughly 50% of production costs for fruit. Therefore, intensive horticultural crops demand specialized labour compared to broad-scale agriculture. Effective use of robots in horticulture is essential. Horticulture uses several sorts of robots, including Demeter for weed control, fruit picking robots, drones, forester robots, robot suits, and Vitirover solar robots. Robots are utilized in horticulture for various tasks such as weeding, crop scouting, micro spraying, irrigation, selective harvesting, sorting, and packing, as well as in parks, golf courts, and polyhouses.

Need of Robotics in Horticulture

- ❖ Labour is a major cost in horticulture. Hiring contributes to over 50% of fruit production expenditures. Intensive horticulture crops demand more skilled labour than broad-scale agriculture.
- ❖ Land mechanization.
- ❖ Reduce crop losses by harvesting at the appropriate time.
- ❖ Skill and availability when needed.
- ❖ Cost of labour
- ❖ Labour experience and skill level are frequently unavailable.
- ❖ Sensor-equipped machines are objective and allow for regular product monitoring.
- ❖ Similar level of output quality

Types of Robots Used in Horticulture

1. Demeter: Demeter is a self-driving robot that can cut crops and resembles a traditional harvester. It is equipped with cameras capable of detecting difference between trimmed and uncut crops. This information guides the machine's movements, including where to drive, where to position the cutter head, and when to turn around at the end of a crop row.

2. Weed controller: The four-wheel drive weed-seeking robot removes and destroys weeds. Crops growing in rows can be weeded by moving a hoe between them. Intelligent hoes use vision systems to identify crop rows and properly drive between them, eliminating the need for herbicides.
3. Fruit picking robot: The robots must avoid injuring the tree's branches and foliage while picking fruits. Robots must have access to all parts of the tree being harvested. The robot can distinguish between fruits and foliage through video image capture. The camera on the robot arm detects colours and compares them to stored attributes in memory. If a match is found, the fruit is harvested. To see hidden fruit, use an air jet to sweep leaves away. The pressure exerted to the fruit removes it from the tree but does not cause it to crash. The gripper form varies with the type of fruit being plucked.
4. Drones: A drone is a flying robot. To acquire a bird's-eye view of the landscape. Provides a quick and easy approach to monitor crop progress and identify areas for replanting or herbicide applications.
5. Forester robot: This robot is specialized for cutting, trimming, and harvesting wood in woods.
   It uses unique jaws and axes to chop the branches.
6. Robo suit: This is specifically designed for tasks such as pulling radishes.
   The suit features eight motors installed on the shoulders, elbows, back, and knees to deliver power to the wearer.
7. Vitirover solar robot: It is a smart, self-sufficient robot. This robot relies on the sun to power its electrical motors. Due to the size of the vineyards, storing energy in a battery and returning to the base for recharging was not practical. With a solar panel, this robot can work for 100 hours continuously.

Use of robotics systems in horticultural crops

Robotic Applications in Agriculture for Sowing and Planting

- The use of planting robots in agriculture represents a shift in farming operations, providing solutions for a variety of crops and planting demands. These automated systems are not confined to a particular type of agriculture, but rather cover a wide range of fields.
- Planting robots may be designed to handle fragile crops like tomatoes, lettuce, and strawberries with the precision needed for optimal growth.

Types of Planting Robots

1. Autonomous tractor robots: Seeding robots are basically driverless tractors fitted with modern navigation systems. They can conduct a variety of tasks, including planting, with accuracy and efficiency.
2. Drone planters: Drones are increasingly being employed for planting, particularly in remote places. They can disseminate seeds over a wide region, making them excellent for reforestation and large-scale grain production.
3. Robotic arm planters: Planting robots, which include robotic arms, are ideal for delicate operations like transplanting seedlings. They are especially beneficial in smaller industries, such as nurseries and greenhouses.
4. Swarm robot planters: These involve a group of miniature robots working together to plant seeds.

They are extremely useful for wide fields since they can cover large areas fast and with consistent accuracy.

5. Specialized planting robots: Seeding robots, which are tailored to certain crops or conditions, can drill holes for seeds, deposit them at precise depths, handle crops with special requirements, and even cover them with dirt. They are commonly employed in specialised crop cultivation, such as orchards or vineyards, and may contain extra functions like as harvesting or weeding.

Pruning Manipulators

Pruning involves removing tiny branches from trees and plants to maintain structure, boost productivity, and reduce disease risk. To prune a branch, a robotic manipulator needs sufficient degrees of freedom (DoF) and an end-effector that can cut the branch. Pruning manipulators were tested in two scenarios: grapevines and apple trees. These manipulators demonstrated that a light-controlled environment can eliminate visual mistakes and prismatic joints can provide a longer reach.

Fig. A Robot System for Pruning Grape Vines

Fig. A Robot System for apple pruning

Harvesting Manipulators

Harvesting manipulators, like pruning manipulators, require sufficient reach and depth of field to reach the target in the correct orientation. Additionally, the end-effector must be able to catch the target fruit without injuring it. Harvesting manipulators were employed for five products: strawberries, tomatoes, apples, sweet peppers, and iceberg lettuce. Harvesting manipulators require varied kinematic configurations for different end-effectors. Some require simply horizontal movement, while others demand more mobility to reach and grab the target.

Fig. Strawberry-Harvesting Robots

Fig. Tomato Harvesting Robots

- Robotic Apple Harvesters
- Robotic Harvesting System for Iceberg Lettuce
- Multipurpose Harvesting Agricultural Robot

Need of Automation and Robotics in Greenhouse Management

- Manufacturing facilities are becoming larger.
- Plant treatment and crop specialisation adapted to each individual.
- The labour cost is rising.
- Skilled worker shortages are becoming a big issue.

- ❖ There are health issues.
- ❖ Product purity and food safety.
- ❖ Market competition exists at both domestic and international levels.

Greenhouse farming promises higher yields and better produce quality by creating a regulated and optimized cultivation environment. This is where robotic technology comes in, supplementing human labour by automating important activities. Robotic systems can be used for operations including as sowing, watering, trimming, harvesting, and more, taking over repetitive and labor-intensive tasks from human personnel. Robotics plays a pivotal role in modern greenhouse farming, revolutionizing the way we cultivate crops. These are:

1. Automating Critical Tasks: Greenhouse farming offers higher yields and better produce quality due to the regulated atmosphere. However, handling many operations efficiently within the greenhouse might be difficult. Here's where robotic technology comes in. Robots do repetitive and labor-intensive operations like sowing, watering, pruning, and harvesting. They use sensors and AI to closely monitor plant health and environmental factors, modifying operations for optimal growth.
2. Precise Harvesting: Automated robotic arms gently select ripe vegetables, increasing harvest productivity. For example, robots with stereoscopic cameras and AI can detect ripe tomatoes and pluck them without damaging the crop. This precision ensures a high-quality yield.
3. Vertical Farming: Robots allow greenhouses to maximize their regulated space by collaborating with people. They enable greater use of vertical farming techniques, reducing resource consumption while ensuring sustainable and high-volume plant production.
4. Robotic Pollination: Pollination is required for certain crops to set fruit. Robotic pollinators have proven to be as effective, if not more so, than manual pollination. These robots optimize fruit production in greenhouses focusing on pollination-dependent crops.
5. Data-Driven Insights: Sensor-equipped robots closely monitor the health of individual plants, collecting real-time data on colour, size, leaf temperature, and moisture stress. This granular data enables new commercial opportunities based on advanced analytics and predictive modelling. Sophisticated yield forecasting models help improve production scheduling, supply contracts, storage, and logistics.

Hence, robots in greenhouses not only increases productivity and efficiency, but also paves the way for long-term, high-quality crop growth.

Conclusion

Agriculture robots can cut cultivation costs by regulating labour and making optimal use of fertilizers and pesticides. Agriculture occupations are time-consuming, risky, and need intellect and quick decision-making, thus robots can be a good substitute for human operators. The use of robots reduces farmer workload and allows field operations to be completed on time. This technique produces higher-quality crops and is best suited for future farming.

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Sustainable Strategies in Quality Control for Horticultural Produce

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Horticultural produce, encompassing fruits, vegetables, flowers, and ornamental plants, plays a pivotal role in the agricultural sector and global food supply. Ensuring the quality of horticultural produce is crucial for maintaining consumer satisfaction, meeting regulatory standards, and enhancing market competitiveness. Quality control in horticultural produce represents a multifaceted endeavour encompassing a spectrum of practices and technologies aimed at safeguarding the integrity, freshness, and safety of these perishable commodities. With consumer expectations evolving and regulatory standards becoming increasingly stringent, the importance of robust quality control measures cannot be overstated. Against the backdrop of a rapidly evolving agricultural landscape, this discourse seeks to unravel the nuances of quality control practices within the realm of horticultural production. By examining the challenges faced, the strategies employed, and the technologies harnessed, we aim to elucidate the pivotal role that quality control plays in sustaining the viability, competitiveness, and resilience of horticultural enterprises in a dynamic global marketplace.

Challenges in Quality Control for Horticultural Produce: Quality control in horticultural produce faces several challenges are given below:

Perishability

Horticultural produce, such as fruits and vegetables, is highly perishable and prone to deterioration during storage, transportation, and handling. Managing the perishability of these commodities presents a significant challenge in maintaining quality and extending shelf life.

Variability in Quality Attributes

Horticultural produce exhibits variability in quality attributes such as size, colour, shape, texture, sweetness, acidity and aroma. Managing this variability and ensuring consistency in quality across batches and varieties requires precise control and monitoring throughout the production and supply chain.

Susceptibility to Physical Damage

Fruits and vegetables are susceptible to physical damage during harvesting, packing, and transportation, leading to bruising, crushing, and mechanical injuries. Minimizing physical damage is crucial for preserving product quality and reducing post-harvest losses.

Environmental Factors

Environmental factors such as temperature fluctuations, humidity levels, and exposure to sunlight can impact the quality and shelf life of horticultural produce. Managing environmental conditions during production, storage, and transportation is critical for preserving freshness and minimizing spoilage.

Supply Chain Complexity

The complexity of the horticultural supply chain, involving multiple stakeholders from farmers to retailers, presents challenges in maintaining quality and traceability. Ensuring seamless coordination, communication, and collaboration among supply chain partners is essential for preserving product integrity and meeting consumer expectations.

Labour Intensity

Quality control in horticultural produce often requires labor-intensive tasks such as sorting, grading, and packaging, which can be time-consuming and costly. Finding efficient and cost-effective solutions for labour-intensive processes is essential for enhancing productivity and competitiveness.

Market Demand and Consumer Preferences

Meeting evolving consumer preferences and market demand for high-quality, fresh, and sustainably produced horticultural produce presents a challenge for producers. Understanding consumer trends, preferences, and expectations is essential for aligning production practices and quality control measures to market needs.

Technological Limitations

While advanced technologies offer opportunities for improving quality control in horticultural produce, there may be limitations in terms of accessibility, affordability, and technical expertise. Overcoming technological barriers and ensuring widespread adoption of suitable technologies is essential for enhancing quality control practices in the horticultural sector.

Strategies in Quality Control for Horticultural Produce: To overcome the challenges associated with quality control in horticultural produce, various strategies and technologies have been developed and implemented:

Pre-harvest Management

Implementing best agricultural practices, such as proper irrigation, nutrient management, pest and disease control, and harvesting at the optimal maturity stage, can improve the quality and yield of horticultural crops.

Post-harvest Handling

Adoption of appropriate post-harvest handling techniques, including sorting, grading, washing, sanitization, and packaging, helps minimize physical damage, reduce microbial contamination, and extend the shelf life of horticultural produce.

Cold Chain Management

Maintaining the cold chain throughout the supply chain, from harvest to retail, helps preserve the freshness and quality of perishable horticultural commodities, such as fruits and vegetables, by controlling temperature and humidity levels.

Quality Assessment Technologies

Integration of advanced technologies, such as spectroscopy, imaging systems, electronic noses, and biosensors, enables rapid and non-destructive assessment of quality attributes, including colour, size, firmness, sweetness, acidity, and aroma, facilitating real-time decision-making and quality control.

Traceability Systems

Implementation of traceability systems, such as barcoding, RFID (Radio Frequency Identification), and block-chain, allows for the tracking and tracing of horticultural produce throughout the supply chain, ensuring transparency, accountability, and authenticity, while also enabling timely intervention in case of quality issues.

Quality Standards and Certifications

Adherence to international quality standards and certifications, such as Global Good Agricultural Practices (Global GAP), ISO 22000, and organic certification, helps establish credibility, enhance market access, and build consumer trust in the quality and safety of horticultural produce.

Continuous Monitoring and Improvement

Establishing robust monitoring systems and protocols for quality control enables continuous assessment and improvement of processes. Regular inspections, quality audits, feedback mechanisms, and corrective actions help identify areas for enhancement and ensure adherence to quality standards throughout the production and supply chain.

Training and Capacity Building

Investing in training and capacity building programs for farmers, producers, and stakeholders is essential for fostering a culture of quality consciousness and continuous improvement. Education on best practices, quality control techniques, and compliance with standards equips individuals with the knowledge and skills necessary to uphold quality standards and meet market demands effectively.

Conclusion

Enhancing quality control in horticultural produce is essential for ensuring consumer satisfaction, meeting regulatory requirements, and driving market competitiveness. By adopting proactive strategies, leveraging advanced technologies, and adhering to quality standards, stakeholders across the horticultural supply chain can optimize the quality, safety, and marketability of produce, thereby contributing to the sustainability and growth of the horticultural industry. Continuous innovation and collaboration are key to addressing emerging challenges and driving continuous improvement in quality control practices within the horticultural sector.

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