Open Access Multidisciplinary Online Magazine

Agri-India TODAY

Monthly e-Newsletter

ISSN : 2583-0910

Volume 04 | Issue 09 | September 2024

www.agriindiatoday.in

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ISSN : 2583-0910

Agri-India TODAY

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Peer reviewed monthly newsletter

Article ID : 04/IX/01/0924

INEQUALITIES IN RESOURCE ALLOCATION IN AGRICULTURE

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Introduction

Resources are essentially economic or productive factors which are used to accomplish an activity or to achieve desirable outcome. In Agriculture "Anything that aids in production is Resource". Some of the major input resources of agriculture are Seed, Fertilizer, Irrigation Plant protection chemicals, Agricultural tools & implements, Credit etc. Inequality meaning disparities in the distribution of a certain metric, which can be income, health or any other material or non-material asset. Inequality can prevail within country inequality on individual or group level, also among countries which is referred as international inequality.

Inequalities in the use of inputs is important because-

- Increase in agricultural productivity can lead to increase in income of poor, reducing income inequality which ultimately leads to faster poverty alleviation.
- Growth in GDP of agriculture sector is four time more important than growth in other sectors for alleviation of poverty.
- For agricultural households, the capacity to buy is the capacity to produce, but production and productivity depends upon the use of resources.
- Access to productive resources such as land, water, and other inputs are keys to higher level of agricultural incomes and poverty alleviation. (IHDS, 2003)
- In addition to increase crop production and consequential farm income, improved irrigation access can significantly contribute to rural poverty reduction within a region. (Chambers, 1988)

Relationship between Growth and Inequality

Inequality also has a very close relationship with Growth. The most important theory of Growth & inequality has given by economist **Simon Kuznets** in 1950s, it is known as '**Kuznet Curve**'.

The theory says when growth is taking place for a country initially inequality will increase and then eventually it will decrease. Inequality rises because people move from low productive primitive(agriculture) sector to high productive modern(industrial) sector, and use of old technologies resulting in low productivity in the primitive sector. Inequality generally widens more in poorer countries, but this is only transitional phase, once they become economically developed, inequality reduces.

Despite its historical significance, the Kuznets Curve has some drawbacks. It is based on structural changes from agriculture to industry, but modern economies also transition to service-based sectors, which may have different implications for inequality. It also assumes a simplistic relationship between economic growth and inequality, ignores the effects of globalisation, and fails to adequately account for the impact of technological advancements.

Measures of Inequality

There are a number of methods of measuring inequality, the most popular ones are-

1. **Gini Coefficient :** Gini Coefficient is the most widely used method of measuring inequality. It was developed by Italian Statistician Corrado Gini in 1912 in his paper named "Variability and Mutability". Calculation is done using Lorenz Curve, a cumulative frequency curve which shows cumulative percentage of the variable on the vertical axis and cumulative percentage of household or population on the horizontal axis. Deviation of the Lorenz curve from the 45-degree line is the measure of inequality. Gini Coefficient ranges from **0-1**, 0 means perfect equality, 1 means perfect inequality.
2. **Atkinson Index :** Named after British economist Anthony Atkinson, this index differs from other inequality measures like the Gini coefficient by explicitly incorporating societal aversion to inequality. This means that the Atkinson Index can reflect how much weight is placed on different parts of the income distribution, particularly the lower end. It includes a sensitivity parameter which ranges from 0 to infinity. Higher value of the parameter indicates more sensitivity. A higher value of ε indicates greater sensitivity to income differences at the lower end of the distribution. If ε is set to zero, the index treats all income equally, effectively becoming insensitive to inequality The Atkinson Index ranges from 0 to 1, where 0 indicates perfect equality (everyone has the same income), and 1 indicates maximal inequality
3. **Coefficient of variation (CV) :** CV is a statistical measure that expresses the extent of income variability in relation to the mean of the population. When applied to income inequality, the CV provides an indication of how income varies across a population relative to the average income. It is particularly useful for comparing income inequality across different populations or time periods. The CV is a relative measure of dispersion, making it useful for comparing the degree of income inequality across different populations with varying mean incomes. Low CV indicates low income inequality, meaning incomes are relatively close to the mean, and high CV indicates high income inequality, meaning incomes are widely dispersed around the mean.
4. **Decile Dispersion Ratio :** A straightforward and widely used measure of inequality is the decile dispersion ratio. This metric compares the average income or consumption of the wealthiest 10 percent (the 90th percentile) to that of the poorest 10 percent (the 10th percentile). It provides a clear interpretation by showing how many times greater the income of the richest segment is compared to the poorest segment. However, this ratio overlooks the incomes of individuals in the middle of the distribution and does not account for the distribution of income within the top and bottom deciles or percentiles.
5. **Generalised Entropy index :** The Theil Index and the Mean Log Deviation Measure are among the most commonly used metrics for assessing inequality, both of which fall under the umbrella of generalized entropy (GE) inequality measures. These measures quantify inequality with values ranging from zero to infinity, where zero indicates perfect equality and higher values denote greater levels of inequality. A key feature of GE measures is the parameter α, which dictates the sensitivity of the measure to income disparities at different points in the income distribution. This parameter can take any real value:
    a. For GE (0), the measure is more responsive to variations in the lower end of the income distribution.
    b. For GE (2), it is more sensitive to differences at the upper end of the distribution.

6. **Kakwani Progressivity index :** The Kakwani Progressivity Index is a measure designed to evaluate the progressivity of a tax system in relation to income inequality. Named after the economist Nanak Kakwani, this index helps determine whether a tax system is progressive, regressive, or proportional, and by how much it affects the distribution of income. The index uses the Gini coefficients of pre-tax and post-tax income distributions to determine the progressivity of the tax system. The Index ranges from -2 to 1. A positive value indicates a progressive tax system, where the tax burden increases with income. A negative value indicates a regressive tax system, where the tax burden decreases with income. A value of zero indicates a proportional tax system, where the tax burden is distributed equally relative to income.
7. **Robin Hood index :** The Robin Hood Index, also known as the Hoover Index or the Pietra Index, is a measure of income inequality that quantifies the portion of total income that would need to be redistributed to achieve perfect equality. The index is named after the legendary figure Robin Hood, who is said to have taken from the rich and given to the poor, symbolizing the redistribution of wealth. The index ranges from 0 to 1 (or 0% to 100%). A value of 0 indicates perfect equality, where no redistribution is needed, and a value of 1 indicates maximum inequality, where all income is concentrated in the hands of a single individual which needs to be redistributed to achieve equality. Calculates the vertical distance between the Lorenz curve and the 45°line of equality. It indicates the proportion of parameter which has to be transferred from the population who lies above mean to those who lies below the mean, to achieve an equal society.

Reason for inequality in resource allocation

A. Land Inequality

1. Increasing sub division of land due to inheritance law & increasing population is one of the major factors of land ownership inequality. (Kaushik, 1993)
2. Coexistence of large estate focusing on the exportable cash crops & small subsistence holding focusing on food crops for the domestic market skews the distribution of land. (Easterly & Levine, 2003)
3. Landowning elites often distributes land among themselves & restricts access of land to indigenous farmers & landless laborers. (Frankema, 2010).

B. Fertilizer inequality

1. The continuously rising prices resulting from supply moderation restrict the access of small farmers to Fertilizer. (Bhogal, 2016)
2. Small & marginal farmers use less fertilizer than Large farmers except Urea. (Jahiruddin *et.al*., 2009)

C. Irrigation inequality

According to the Report of CGIAR Challenge Program on 'Water and Food(CPWF)-Addressing water, food and poverty problems together: Methods, tools and lessons', 2013, the reasons are-

1. Irrigation charges are high for small & marginal farmer to afford, even the rental of engine driven pumps is beyond their capacity.
2. Most of the irrigation devices are suitable for medium to large scaled farmlands.
3. Often irrigation options are developed for medium & large farmers who compose only 15-20% of the population.

D. Credit Inequality

1. It is argued that benefits of institutional credit are largely accrued to the richer section of a region.
2. Level of education greatly affects the probability of credit taken from institutional sources.
3. Complex procedure of getting institutional credit often discourages less educated farmers to get access to them.

Impact of Inequality

- Rising asset inequality by 1 percentage point is estimated to knock off overall growth of a country by 10 percentage point. (OECD Report, 2014)
- 1 percent increase in Gini coefficient reduces agricultural output by 0.04%. (Nicholas, 2010)
- Increase in Gini Coefficient by 1 percentage point reduces GDP per capita by around 1.1% over a five-year period. (Bruckner & Lederman, 2015)
- Rising inequality restricts reduction in poverty. (Gould, 2014)
- Indirectly inequality creates oppressive social relationship. (Faguet *et al*. ,2016)
- Land ownership inequality often leads to high level of income inequality. (Carter, 2000)
- Land inequality retards human capital accumulation. (Deininger & Squire, 1998; Deininger & Olinto, 1998)
- Less access to institutional credit reduces investment in agricultural thus restricting the growth of the sector. (Kumar *et al*., 2010)

Conclusion

The disparities in resource allocation within the agricultural sector pose significant challenges in achieving equitable and sustainable growth. Inequalities in the distribution and access to essential agricultural inputs such as land, fertilizers, irrigation, and credit not only hinder productivity but also exacerbate poverty and social inequality. The evidence underscores the critical role of integrated and equitable resource management in fostering agricultural productivity and poverty alleviation. Addressing these inequalities requires comprehensive policy interventions that promote fair access to resources, particularly for small and marginal farmers. Strategies such as land reform, subsidies for essential inputs, improved access to credit, and the development of irrigation infrastructure tailored to small-scale farming can mitigate these disparities. Therefore, fostering equitable resource distribution is not only a moral imperative but also a strategic approach to achieving inclusive and sustainable development in the agricultural sector.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/02/0924

IMPACT OF DEFORESTATION ON ENVIROMENT

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Abstract
Deforestation has caused the forest to crumble and disintegrate in a number of countries, which has had a high risk of impacting the forest ecosystem, plant structures, and wildlife extinction. Regrettably, deforestation has a negative impact on the sustainability of the ecosystem worldwide, with emerging nations being more severely affected. Among the effects of deforestation are worldwide human life, which may result in destitution. According to research, at least 70% of people in developing nations are impoverished. This essay discusses deforestation on a worldwide scale, its advantages, how it impacts human existence, and how we should work with the appropriate authorities to halt the harm that tree-cutting causes to the ecosystem.

Introduction

The process of a forest ecosystem being generally disrupted by large-scale tree cutting is known as deforestation. It also refers to any action that modifies the natural tree covers, such as clearing an area of all trees, thinning a forest, or lighting bushes on fire. People cut down trees for a variety of purposes. Some of these include creating charcoal from the wood that is sold or used as fuel, or using the wood to create houses, communities, or cattle pastures. Lack of reforestation or sufficient planting after tree removal can lead to habitat loss, biodiversity loss, and aridity. Tree removal may also be utilized in battle to deny the opposition protection for its forces and essential supplies Numerous of the planet's fragile ecosystems are always in danger due to the serious dilemma of deforestation. Deforestation is still a hazard to the ecosystem even though its consequences are well-known and have been repeatedly recorded. Scientists and researchers from all over the world have issued numerous warnings about this effect.

Deforestation and it's impact on environment

This is the process by which vast tracts of land are stripped of trees for a variety of causes. We are seriously harming the environment by destroying, burning, and otherwise ruining the forests, which will have disastrous effects on future generations. In this essay, I will examine the causes of deforestation and how it affects the environment. In order to stop the loss of rainforests worldwide and guarantee that resources are available for future generations, I will also consider any steps implemented to reduce deforestation. Despite deforestation's detrimental effects on the environment, there are a variety of explanations for it. Due to urbanization in some places, people require wood and wood from trees to manufacture paper, houses, and buildings. It is employed in both industrial and commercial settings.

In addition, trees may hold aesthetic, recreational, commercial, historical, cultural, and religious significance for people. The economic value of timber and other forest products is significant both domestically and internationally. The individuals who gather the wood benefit economically from deforestation as well. There are other additional forest products other than timber from deforestation, which can be used by herbalists, rubber tappers, hunters, and gatherers of berries, nuts, bamboo, and fungus. Additional non-timber forest products include textiles, dyes, and medicinal substances. Numerous people rely on forestlands for their primary source of income. About one-third of the global population uses wood as fuel, making it a substantial source of energy.

Peasant farmers are motivated by the fundamental human need for food and frequently clear forests to increase crops for self-sufficiency. The majority of people in tropical countries live in extreme poverty, with farming serving as their primary source of income Farmers in these nations must grow crops for food and profit since they lack the funds to purchase necessities. The expansion of roads is a primary factor contributing to deforestation in the Amazon. There is a need for additional highways and roads as a result of the recent expansion of areas in the Amazon. Over the past 20 years, the construction of highways has encouraged new and convenient access to forested areas. This growth in conjunction with regional development incentives from the government.

Main reason which are responsible for deforestation

It is difficult to imagine that 90% of the planet was once covered in trees, but that is exactly what happened. If so, one naturally wonders, then what became of all these trees? Why do individuals fell trees? These are plausible explanations:

a) Demand for land for cultivation

This has been observed in Kenya as well as other places across the world, particularly in nations where agriculture is the main driver of their economies. Trees have been felled by both governments and private citizens to create space for the production of cash and subsistence crops.

b) Need for firewood

People utilize firewood as a source of heat, particularly those who reside in rural areas without access to gas or electricity. Here, trees are felled and burned.

c) Need for wood for furniture, pencils, paper etc

While it is necessary to meet the aforementioned needs, chopping down trees is not the most likely way to solve these issues. Why? This is due to the fact that most people who remove trees do not plant new ones in their stead. Moreover, even if felling trees is the only way to meet the aforementioned requirements, plant two for each one that is taken down won't stop the desert from growing. This is a result of how long it takes for trees to develop and mature, particularly hard wood trees. The following risks arise from deforestation.

d) Destruction of animal habitat

All other creatures require woods as their home, with the exception of domesticated animals and those found in fresh and saltwater waters. In addition to giving the animals a place to roam throughout the day, these forests also supply food and, via camouflage, serve as a source of protection from predators. In actuality, animals die when their habitats are destroyed.

e) Medicinal Plants

Certain trees have herbal uses. Since ancient times, people have utilized trees like the Cinchona to treat malaria. The loss of these forests results in the extinction of therapeutic plants that could be utilized to cure a variety of illnesses.

f) Greenhouse effect and global warming

The flow of nutrients and energy is balanced by nature. In certain cycles, such as the carbon cycle, where deforestation results in the persistence of carbon dioxide in the atmosphere, forests play a critical role. Carbon dioxide buildup.

Solution to control the deforestation

a. Three trees, not two, should be planted in the place of each tree that is chopped down. We've come to a crucial juncture where planting a lot more trees will be necessary to stop the planet from becoming a desert.
b. Water catchment regions should be rigorously left alone unless absolutely required.
c. For commercial purposes, such as the production of paper, pencils, and furniture, fast-growing soft wood tree species should be planted.
d. Consistent global mass education about the value of reforestation and the risks of deforestation should be implemented.
e. Global legislation prohibiting deforestation must be passed and strictly enforced.
f. It is imperative that we cease using charcoal as a fuel source.

Nature functions as a complete cycle. This is evident in the many energy and nutrition cycles as well as in animals where predator and prey coexist. As was previously mentioned, woods are important to this equation. The understanding of conservation

Conclusion

There may be adverse effects of deforestation on the environment. The loss of millions of species' habitat has the most dramatic effects. Since forests are home to 80% of all terrestrial animals and plants on Earth, many of them are unable to withstand the deforestation that obliterates their habitat. Climate change is also caused by deforestation. Deforestation is therefore a crucial topic that needs to be addressed. It negatively impacts the lives of all living things. Due to the increasing loss of trees, deforestation has become a major worry in modern society. Trees are taken down for farming, paper product production, animal husbandry, and other purposes. Forests and trees are turned into farmland in order to feed the planet's growing population. The globe is now in danger because of this, and the rate of forest decline is observed to be rising quickly. The Earth has warmed as a result, resulting in high temperatures. This pattern would carry on for the upcoming years unless appropriate action is taken to stop deforestation. There are fewer trees now because of deforestation. Additionally, it has significantly reduced the importance of certain ecosystems on Earth. Humans are highly adaptable, but if significant afforestation efforts are not undertaken, they may not be able to withstand the extreme climate.

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ISSN : 2583-0910
Agri-India TODAY
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Article ID : 04/IX/03/0924

CUSTOMIZING STARCH PROPERTIES IN PLANTS AND BEYOND

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Abstract
Starch is the most common and abundant storage carbohydrate in cereal crops, essential for nutrition and widely used in the food, medical, and processing industries. However, native starches have limited applications, restricting their industrial use. To enhance beneficial characteristics and overcome the limitations of native starches, modifications are introduced. These modifications produce novel polymers with diverse functional and value-added properties tailored to industry needs. Starch modifications can occur in-plant through genetic engineering or outside the plant using physical, chemical, and enzymatic methods. Recent discoveries of genes involved in starch metabolism have enabled direct modification within plants, the most cost-effective way to tailor specific starch properties. Chemical modifications involve oxidation, etherification, esterification, and acid hydrolysis to introduce new functional groups, altering the starch's physicochemical properties. Physical modifications are categorized into thermal methods (pregelatinization, extrusion, heat-moisturizing, annealing, microwave treatments) and non-thermal methods (ultra-high pressure, ultrasonification, pulse electric fields). Enzymatic modification utilizes endoamylases, exoamylases, debranching enzymes, and transferases to adjust starch properties. Understanding these modification techniques can lead to starch-based products with targeted structures and optimized properties for specific applications.

Keywords : Starch modification, gene manipulation, physical, chemical, enzymatic

Introduction

Starch is a homopolysachharide found abundantly in nature, serving as a primary energy and nutrient source for humans and animals. It is a major diet component for more than half of the world's population. Many human diseases are associated with the diet composition, with diabetes being one that requires careful dietary management. Consequently, maintaining health necessitates greater attention, which can be achieved through limiting the intake of carbohydrates. In response, research is focusing on developing plants that produce customized, safer foods to lower disease risk and achieve widespread acceptance**.**

There are essentially two types of starch: storage starch and transitory starch. The quantity of storage starch is much higher than that of transitory starch, making it more commercially valuable. Starch is biosynthesized as semi-crystalline granules composed of amylose and amylopectin. Both are chemically made up of α-D-glucose units, with linear chains formed by α-1,4-glycosidic linkages and branching points introduced by α-1,6 glycosidic bonds (Apriyanto *et al*., 2022).

Starch is a versatile biomaterial that is particularly valued for its abundance, low cost, non-toxicity, and biodegradability, making it suitable for various food and non-food industries. It is widely used in many dairy and bakery products, soups, sauces, coatings, and meat products. Moreover, there is a high demand for starch in non-food industries as a renewable material. The demand for modified starch in processed foods is high, and its significant social and economic impact on human life suggests that starch modification area will be booming in the future. The modification can be done outside the plant system by using chemical, physical and enzymatic methods or in plant by using genetic engineering approaches.

Methods of starch modification

In-plant Starch Modification

In-plant starch modification is the most cost-effective method for tailoring specific starch properties for various applications. Recent gene discoveries involved in starch metabolism have opened new pathways for modifying starch directly within plants. Parameters such as starch amount, granule morphology, size, inner structure, and phosphorylation can be adjusted. Mutants, valued in the food sector for their unique traits, help identify new starch functions. Although most research has focused on plant models like *Arabidopsis thaliana*, studies on starch metabolism in other plants, particularly starch-producing crops, are increasing. These research shows that starch metabolism is evolutionarily conserved, making it easier to apply findings from model species to crop-producing plants.

Chemical method

The physiochemical properties of the starch molecules changes with the introduction of new functional groups like acetyl-, carboxyl-, ethyl-, etc. which behave as electrophile during reaction (Compart *et al*., 2023). The types of chemical modification include- cross-linking, oxidation, etherification, esterification, grafting and acid hydrolysis. The type of chemical modification is chosen based on the desired outcome.

Cross-linking

The hydroxyl group present in starch molecules reacts with the multifunctional reagents and forms an ester or ether linkages. It causes to increase starch solubility in organic solvents, degree of polymerization and also shows resistance to heat and acids. The starch modified by cross-linking shows reduced retrogradation, better paste quality and increased viscosity (Wang *et al*., 2020). Cross-linking is the most commonly used in food industry as a viscosifiers and texturizers for dairy products, in pharmacy for a transport of molecules, in bioplastics and also in wastewater management.

Oxidation

The oxidation of modified starch causes conversion of hydroxyl groups into carbonyl and carboxyl groups, leading to the breakdown of amylose and amylopectin which gives better gel texture, film adhesion and stability. The chemicals such as dichromate, periodate, hydrogen peroxide and hypochlorite are used as an oxidizing agent. The use of the chemicals causes production of toxic byproducts, so they need to be properly treated. The use of ozone as an oxidising agent is a great alternative for these chemicals as it is eco-friendly, leaves no toxic residue and can be generated at the production site.

Etherification

Etherification involves the introduction of lipophilic functional groups that increases the water resistance of starch (Watcharakitti *et al*., 2022). Starch ethers are produced by the hydroxypropylation, carboxymethylation and hydroxyethylation among which carboxymethylation called green polymer and have high hydrophilicity. It is used in pharmaceutical industry for drug delivery system and also in waste water treatment to remove heavy metal ions.

Esterification

Esterification occurs at the hydroxyl groups at the C3, C2, and C6 positions, with reactivity increasing in that order. This process creates organic and inorganic starch esters. It reduces the hydrogen bonding capacity of amylose or amylopectin, leading to increased hydrophobicity, swelling capacity, and reduced retrogradation. Organic esterification, like succinylation, lowers gelatinization temperature and retrogradation while enhancing thickening, viscosity, and water retention. Inorganic esterification, such as phosphorylation, improves viscosity, pasting transparency, and gelatinization. Esterification is widely used in paper production, pharmaceuticals, and food processing.

Acid hydrolysis

Acid hydrolysis of starch is conducted at temperatures below the gelatinization point, enhancing properties like solubility, pasting viscosity, gelatinization enthalpy, and swelling power. The impact on granular morphology varies with species, tissues, and hydrolysis levels. Various acids can break the glycosidic bond, with nitric, sulfuric, and phosphoric acids being the most common. The acid initially affects the starch granule surface before penetrating its inner structure. This modification is primarily used in the food, paper, and textile industries.

Enzymatic modification

These kinds of modifications involve use of enzymes to alter starch properties and are primarily applied in the food industry. The enzymatic modification generally categorized into four types: endoamylases, exoamylases, debranching enzymes, and transferases.

Endoamylase

A well-known example of the endoamylase category is α-amylases. These enzymes randomly hydrolyze starch at any α-(1,4)-linkage within the amylose and amylopectin, thereby reducing their chain length. The type and concentration of the enzyme used influence how α-amylase can create pockets on the surface of starch granules.

Exoamylase

Exoamylases, including β-amylases, amyloglucosidases, and α-glucosidases, act on the external glucose residues of amylose or amylopectin. This results in the production of β-limit dextrins (by β-amylase), maltose, and glucose (by glucoamylase and α-glucosidase). Enzymatic modification with β-amylases creates multiple cracks on the starch granule surface. Compared to native starch, enzymatically modified starch has higher solubility but lower swelling capacity and pasting viscosity.

Debranching enzymes

The debranching enzyme category includes isoamylase and pullulanase. These enzymes hydrolyze the α-1,6 glucosidic bond. The key difference between them is that pullulanase can hydrolyze the α-1,6 glycosidic bond in both starch and pullulan, while isoamylase only hydrolyzes this bond in glycogen and starch. They produce linear glucans by specifically degrading amylopectin.

Transferase

Transferases, such as amylomaltase, cyclodextrin glycosyltransferase, and amylosucrase (Seo *et al*., 2020) hydrolyze the α-1,4 glycosidic bond of a donor molecule. They transfer the cleaved residue to a glycosidic acceptor, forming a new glycosidic bond in the process.

Physical modifications

Nowadays, physical modification has become an important starch modification method because it is economical and eco-friendly method for altering starch properties. These modifications adjust starch's functional properties by controlling temperature and moisture without adding foreign substances.

Hydrothermal Treatment

Hydrothermal treatment, a physical modification method, preserves the surface characteristics of starch granules and maintains starch structure better than other physical methods. Common techniques include annealing (ANN), heat moisture treatment (HMT), and superheated steam (SS). ANN and HMT are conducted above the glass transition temperature but below the gelatinization temperature (Dutta *et al.*, 2022). The SS method heats starch above its saturation point as steam is released under pressure, making it more energy-efficient than conventional hydrothermal methods, saving 50–80% of energy. This efficiency is due to the high heat transfer coefficient of superheated steam, which increases starch molecule mobility and promotes modification.

Pregelatinization

Pregelatinized starch features a unique structure, characterized by porosity from broken hydrogen bonds, with the crystalline regions in the starch particles completely or partially destroyed. This modification grants it properties like cold-water solubility and higher viscosity compared to natural starch, reducing processing time and heat loss in later applications. Pregelatinized starch is commonly used as a thickener in instant foods, such as baby food, instant soups, and desserts, requiring only hot water and stirring before serving. This physical modification significantly alters starch's viscosity, water-binding ability, and gel structure.

Microwave

Microwave treatment uses electromagnetic radiation at frequencies between 300 MHz and 300 GHz. This efficient and eco-friendly method modifies starch by causing high-frequency vibrations in the electric field, continuously reorienting polar and ionizable molecules. These molecules then rub together and collide with surrounding molecules through electromagnetic induction, generating heat. Microwave technology's ease of use, eco-friendliness, and sustainability make it a promising method for starch modification. Additionally, it can increase the resistant starch content in native starch, offering a new approach for developing low glycemic index products.

Ultrasonication

Ultrasonication, using frequencies above 20 kHz to agitate particles, induces acoustic cavitation, which involves the rapid formation and collapse of bubbles in a liquid due to heat and pressure. Ultrasonication creates cracks and cavities on the granule surface, enhancing water solubility and rheological properties (Bonto *et al.*, 2021). This modification is valuable for producing biofuels and for pharmaceutical applications, such as preparing nanoparticles for drug delivery.

Ultra-High Pressure

Starch can also be modified using ultra-high pressures (100–1000 MPa), a green and eco-friendly technique that alters non-covalent chemical bonds with minimal impact on covalent bonds. This method increases swelling power and solubility, delays retrogradation, and significantly changes thermal and pasting properties, as well as the levels of resistant, fast, and slow digestible starch (Castro *et al.*, 2020). Ultra-high pressure is commonly used in food processing.

Conclusion and future prospects

The modified starch offers superior physicochemical properties compared to native starch, expanding the market for starch byproducts. The utilization of starch has significantly increased, driven by advancements in modification technologies tailored to specific applications. Various methods, including physical, chemical, enzymatic, and genetic modifications, have been developed to enhance starch properties. The demand for modified starch with enhanced functionality and sustainability is increasing due to global population growth. Future research will focus on eco-friendly modification methods and exploring new starch sources. The development of novel technologies for precise starch modification is crucial for meeting specific industrial demands. Although significant advancements have been achieved in starch analytics, limitations in time and spatial resolutions still exist. Therefore, it is crucial to establish and develop new starch analytical techniques in the future.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/04/0924

COMPARATIVE ECONOMIC ANALYSIS OF BUTTON MUSHROOM CULTIVATION

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Abstract
Button mushrooms are economically important mushrooms due to their high yield, fast growth, and versatility in culinary applications. They provide a valuable source of nutrition and income for growers, contributing to both local and global markets. Throughout the country, various substrates have been used for growing button mushroom based on availability. This study presents a comparative economic analysis of button mushroom (*Agaricus bisporus*) cultivation using different substrates. The research examines the cost-effectiveness, yield, and profitability of various substrate materials in mushroom production. The findings highlight the significant impact of substrate choice on the overall profitability of mushroom farming, providing valuable insights for growers seeking to optimize their production processes and maximize economic returns in a competitive agricultural market.

Key words : Button Mushroom, cost effectiveness, economic returns, substrate, yield

Introduction

India has reached at 4th largest mushroom producing country in the world with a production of around 3.36 million tonnes. Button mushroom is the highest cultivated mushroom with around 70% share in production. It holds significant economic importance due to high yield potential, fast growth rate, and consumer acceptance at mass scale. These mushrooms are a major component of the country's burgeoning mushroom industry, providing a valuable source of nutrition that supports both local diets and international export markets. Their cultivation requires relatively low input costs and minimal land area, making them an accessible and profitable crop for small and medium-sized farms. The versatility of button mushrooms in diverse recipes further drives their demand, contributing to their status as a staple in both domestic and commercial kitchens across India.

Economic analysis of button mushroom cultivation in India reveals the critical role of substrate choice in optimizing profitability. Utilization of different substrates impacts the cost-effectiveness and yield of mushroom production. By comparing the performance of these substrates, growers can identify the most economically viable options, balancing input costs with potential revenue. This analysis helps farmers make informed decisions, enhancing production efficiency and market competitiveness. The insights gained from such economic evaluations are crucial for maximizing returns and fostering sustainable growth in India's mushroom industry.

Formula for compost preparation with mustard straw for button mushroom

Method 1		Method 2	
Mustard straw	1000 Kg	Mustard straw	1000 Kg
Chicken manure	900 Kg	Cotton waste	150 Kg
Wheat bran	50 Kg	Wheat bran	50 Kg

Method 1		Method 2	
Urea	10 Kg	Urea	17 Kg
Gypsum	100 Kg	Gypsum	100 Kg
Nitrogen	1.77%	Nitrogen	1.77%

Comparative economic analysis of button mushroom

The analysis is presented for case study of a mushroom farm in Himachal Pradesh for one crop cycle of button mushroom. Table 1 presents the comparative economic analysis of button mushroom under 3 different substrates viz, wheat straw, paddy straw, and mustard straw. The total cost includes both depreciation and variable cost on raw material, labour and energy cost. The highest returns were observed in mustard straw followed by paddy straw and wheat straw.

Additionally, operating ratio measures the efficiency by comparing operating expenses to returns, indicating how well the farm manages operational costs. A lower ratio suggests higher profitability and better cost control, providing valuable insights into financial health and competitive performance of the mushroom farm. Operating ratio is also least for the mustard straw showing its profitability and better competitive performance than other straws.

Table 1. Comparative economic analysis of button mushroom with 3 different substrates

Cost/ Returns	Wheat straw (000 Rs)	Paddy straw (000 Rs)	Mustard straw (000 Rs)
Raw material cost (1)	11.68	4.88	6.71
Electricity cost (2)	1.00	1.00	1.00
Labour cost (3)	6.00	6.00	6.00
Compost cost (4) (1+2+3)	18.68	11.88	13.71
Compost cost Rs/ kg compost	9.95	7.19	7.68
Sale of mushroom	36.86	30.43	43.13
Spawn cost (5)	2.68	2.36	2.23
Casing cost (6)	1.61	1.42	1.34
Total Variable Cost (TVC) (4+5+6)	22.96	15.65	17.28
Returns	13.89	14.78	25.85
Operating Ratio	0.62	0.51	0.40

From table 1, it is evident that the cost of compost preparation is highest for wheat straw substrate (Rs. 9.95/ kg compost) followed by mustard straw (Rs. 7.68/ kg compost), and paddy straw (Rs. 7.19/ kg compost). Although the returns are highest for mustard straw based mushroom (Rs.25850), followed by paddy straw (Rs. 14780) and least for wheat straw based mushroom (Rs. 13890).

Conclusion

This advantage arises from the affordability of mustard straw and its high biological efficiency. Since composting costs account for 50-60% of the total mushroom production expenses, choosing the right substrate is essential for growers. The study therefore concludes that mustard straw offers greater profitability for mushroom cultivation compared to other substrates like paddy straw, allowing for cost reductions and enhanced financial outcomes. Adopting mustard straw can lead to more sustainable and economically viable mushroom farming practices, helping growers maximize their returns and improve overall production efficiency.

ISSN : 2583-0910
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Article ID : 04/IX/05/0924

ARKA SAVI: THE BREAKTHROUGH ROSE REVOLUTIONIZING FLORICULTURE

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Introduction

In the world of horticulture, where beauty and science intersect, the development of new plant varieties can redefine industry standards and market dynamics. One such remarkable innovation is Arka Savi, a rose variety developed by the ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru, Karnataka. This rose is not just an aesthetic triumph but a robust, high-yield variety that promises to revolutionize floriculture both domestically and internationally. In this article, we delve deep into the story of Arka Savi, exploring its origins, characteristics, cultivation practices, and its significant impact on the floriculture industry.

The Genesis of Arka Savi

Arka Savi was born out of IIHR's dedicated research and breeding programs aimed at creating a rose variety that excels in both beauty and resilience. The institute, renowned for its contributions to horticultural science, focused on developing a rose that could meet the growing demands of the floriculture market, particularly in terms of shelf life, disease resistance, and high yield.

Unique Characteristics of Arka Savi

Arka Savi is part of the floribunda group, known for their ability to produce large clusters of flowers. This variety stands out for its striking purple-pink flowers, categorized as Red Purple (Group 66-A on the RHS color chart). However, its beauty is only the beginning of its remarkable attributes.

1. **Visual and Sensory Appeal:**
   - The flowers of Arka Savi are characterized by their deep, velvety red purple color with slow twisted opening. This combination makes them an excellent choice for ornamental gardening and for loose flower production.
   - The blooms are medium in size and well-formed, with a velvety texture that adds to their allure. The flowers are testament to meticulous breeding designed to achieve the highest standards of aesthetic appeal.

2. **Yield and Shelf Life:**
   - Arka Savi is a high-yielding variety, capable of producing up to 30 tons per acre per year. This makes it a highly productive option for commercial growers.
   - One of the significant advantages of Arka Savi is its long shelf life. The flowers can remain fresh for 5-6 days, which is considerably longer than many traditional varieties. This extended shelf life is crucial for both local markets and exports, providing flexibility in harvesting and marketing.
   - The long shelf life of flowers makes it ideal for floral decorations, and garlands.
3. **Growth Habits and Disease Resistance:**
   - This variety exhibits vigorous growth and prolific blooming, with a bushy, upright growth habit reaching heights of 5-6 feet. The sturdy stems and large blooms make it ideal for creating stunning floral displays.
   - Arka Savi is resistant black spot which is the most problematic disease resulting in defoliation. This resistance reduces the need for chemical treatments, making it an eco-friendly choice for growers.
4. **Adaptability:**
   - Arka Savi thrives in various climatic conditions across India, from the cooler regions of the north to the warmer, humid climates of the south. Its adaptability makes it a versatile option for growers in different regions.

Cultivation Practices

Growing Arka Savi successfully involves several essential horticultural practices. Here's a detailed guide to help growers achieve the best results:

1. **Site Preparation:**
   - Choose a sunny location with well-drained soil. Roses require at least 6-8 hours of direct sunlight daily.
   - Sandy loam soil with a pH of 5.5 to 6.5 is best suited cultivation. In case of clay soil, raised beds approximately 3 feet wide and 1.5 feet high are recommended for better drainage and crop management.
   - Incorporate organic matter, such as compost or well-rotted manure, into the soil to enhance fertility and structure
2. **Planting:**
   - Rainy season is ideal for planting.
   - Plant roses in the early morning or late afternoon to avoid the midday heat. Space the plants adequately to ensure good air circulation, which helps to prevent disease.
   - Because of the robust growth of the variety, spacing between rows can range between 6-8 feet depending upon the inter cultivation machineries available. Distance between the plants can be maintained at 2-3 feet.
   - Water the plants thoroughly after planting to help establish strong roots.
3. **Watering:**
   - Regular watering is crucial, especially during the growing season. Water to the base of the plant to keep the foliage dry and reduce the risk of disease. Drip irrigation is an effective method for providing consistent moisture without wetting the leaves.

4. **Fertilization:**
   - Apply a balanced fertilizer, including urea, superphosphate, and enriched farm yard manure, to promote healthy growth and abundant flowering. Follow a fertilization schedule tailored to the specific needs of roses, usually every 4-6 weeks during the growing season.
   - Nutrient dose recommended is N:P:K at 240:80:280 kg/acre per year. Soil application of micronutrients $FeSO_4$ and $ZnSO_4$ at 1 gm/plant and 10 gm of $MgSO_4$ per plant 2-3 times in a year will boost the growth of the plant.
5. **Pruning:**
   - Prune roses just before the rainy season to remove dead wood and shape the plant. Pruning enhances air circulation and light penetration, which are crucial for healthy blooms.
   - Remove any weak or crossing branches to prevent overcrowding and improve the overall structure of the plant. It is essential to seal the cut ends after pruning with paste of copper oxy chloride
   - Flowers comes in bunch, once the harvest of blooms on the bunch gets completed, pruning below the bunch will enhance the production.
6. **Pest and Disease Management:**
   - Regularly monitor for pests such as thrips, aphids and spider mites. Integrated pest management practices including the use of natural predators and organic treatments can help to control infestations.
   - Maintain good garden hygiene by removing fallen leaves and debris that can harbor diseases. Ensure adequate spacing and proper watering practices to reduce the risk of fungal infections.

Economic and Market Impact

Arka Savi’s introduction has significantly impacted the floriculture industry, offering numerous economic benefits. Its high yield and long shelf life make it an attractive option for commercial growers, leading to increased marketability and export potential. The variety’s resilience to diseases reduces the need for chemical treatments, lowering production costs and promoting sustainable practices.

Success Story: Mr. Venkatesh’s Arka Savi Journey

Mr. Venkatesh, a farmer cultivating Arka Savi in Ajjvara village, Chickballapur district observed that flowering begins within two months after planting. Each acre accommodates 1,800 grafts of Arka Savi, with a spacing of 8 feet (row to row) * 3 feet (plant to plant). Before planting, he applied 5 tonnes of farmyard manure and also applied DAP, magnesium sulfate, potash, and bio-fertilizers one week prior to planting. To control pests such as thrips and mites, he avoided repeating the same chemicals. Black spot and powdery mildew were managed effectively through a rotation of prophylactic and control sprays. He provides both nutrients and micronutrients every two months and irrigates every 3 to 5 days, depending on temperature and other parameters.

Pinching to encourage vegetative growth was done after two months. Initially, the yield was around 5 kg per acre, but after 8 months, it increased to 50-60 kg of flowers per day per acre. After one year, the yield reached 100 kg per acre daily, with an annual total of approximately 20 tonnes per acre. The flowers are noted for their long shelf life of up to 8 days, which facilitates long-distance transport. Additionally, Arka Savi is sold at Rs. 30-40 more per unit than other varieties such as Mirabul and Mango Yellow. An acre can be managed comfortably by two family members and recently, they have begun exporting Arka Savi to Australia.

Success Story: Mr. Mahesh's Thriving Arka Savi Venture

Mr. Mahesh, a floriculture farmer from Mandya, has made impressive strides with his Arka Savi cultivation. He has been cultivating Arka Savi on an area of 0.625 acres (25 guntas) since November 2023. He planted 1,150 Arka Savi grafts with a spacing of 8 feet by 3 feet. Mr. Mahesh embarked on a journey of growth and success. His commitment and strategic approach have paid off remarkably. Harvesting 25 to 30 kg of flowers every alternate day, he sells his produce at a fixed rate of Rs. 100 per kg. This consistent pricing, regardless of market fluctuations, has allowed him to maintain stability and focus on quality.

Mr. Mahesh's keen observation reveals that growers near Bangalore and Chickballapur have a distinct market advantage, potentially leading to even higher profits. Supported by two family members, he efficiently manages the harvest and expresses great satisfaction with the results. To date, Mr. Mahesh has invested Rs. 1.5 lakhs in cultivation. His dedication has generated a gross income of Rs. 3.6 lakhs, with expectations of an additional Rs. 2 lakhs from his 25 guntas of land. His success story is a testament to the potential of Arka Savi cultivation and the rewards of innovative farming practices.

Future Prospects and Continued Innovation

The success of Arka Savi highlights the importance of continued research and development in horticulture. IIHR's commitment to innovation ensures that new, improved varieties will continue to emerge, meeting the evolving demands of both growers and consumers. Future research may focus on enhancing the existing traits of Arka Savi, such as improving disease resistance further or developing new color variations.

Conclusion

Arka Savi is more than just a rose; it represents the pinnacle of horticultural science and innovation. Its vibrant color, enchanting fragrance, and robust growth make it a stand out choice for gardens and floral arrangements alike. Arka Savi continues to bloom, bringing beauty, joy, and economic benefits to all who encounter it. The variety's success story is a beacon of hope and inspiration for the floriculture industry.

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/06/0924

BIOCHAR: A SUSTAINABLE SOLUTION FOR SOIL HEALTH AND CARBON SEQUESTRATION

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Introduction

Biochar, a carbon-rich material derived from the thermal decomposition of organic matter under limited oxygen conditions, has emerged as a significant tool in sustainable agriculture. Its potential to improve soil health, enhance crop productivity, and contribute to carbon sequestration has made it a focal point for both researchers and policymakers. This article delves into the preparation, application, economic aspects, and policy support surrounding biochar, emphasizing its growing importance in modern agriculture.

What is Biochar?

Biochar is a type of charcoal produced through pyrolysis, where organic materials such as wood, crop residues, or manure are heated in the absence of oxygen. This process results in a stable carbon structure that can persist in soils for extended periods, ranging from centuries to millennia. The characteristics of biochar, including its porosity, surface area, and nutrient content, vary depending on the type of biomass used and the specific pyrolysis conditions.

Molecular Composition, Nutrient content, and Structure

Biochar is composed primarily of carbon, along with varying amounts of hydrogen, oxygen, nitrogen, and ash. The molecular structure of biochar is highly porous, with a large surface area that facilitates interactions with soil particles and microorganisms. Typical nutrient percentages in biochar include: **Carbon (C):** 50-90%, **Hydrogen (H):** 0.5-3%, **Oxygen (O):** 5-15%, **Nitrogen (N):** 0.5-3%, **Ash Content:** 1-15% (depending on the feedstock).

The high carbon content contributes to biochar's stability and its ability to sequester carbon for long periods. The porous structure of biochar enhances its capacity to retain water and nutrients, making it a valuable soil amendment.

Preparation of Biochar

Biochar production involves several pyrolysis techniques, each with distinct temperature ranges, durations, and feedstock requirements:

1. **Slow Pyrolysis:**
    - **Temperature:** 300-700°C
    - **Duration:** Several hours
    - **Feedstock:** Wood, crop residues, animal manure
    - **Output:** High biochar yield, lower amounts of bio-oil and syngas
2. **Fast Pyrolysis:**
    - **Temperature:** 400-600°C
    - **Duration:** Seconds to minutes
    - **Feedstock:** Wood chips, agricultural waste
    - **Output:** Higher bio-oil and syngas yield, lower biochar production

After pyrolysis, the biochar is cooled and can be processed by grinding to achieve the desired particle size for specific agricultural applications.

Application Methods and Dosage in Agriculture

The effectiveness of biochar in agriculture depends significantly on its application method and dosage:

1. **Application Methods:**
    - **Soil Incorporation:** Biochar is mixed directly into the soil, typically at depths of 10-30 cm. This method is most effective for enhancing soil properties such as fertility, water retention, and aeration.
    - **Surface Application:** Biochar is spread on the soil surface and left to integrate naturally through weathering or microbial activity. This method is less labor-intensive but may be less effective in achieving immediate soil benefits.
    - **Seed Coating and Pelleting:** Biochar is used as a seed coating or incorporated into fertilizer pellets to enhance germination and early plant growth.
    - **Compost Blending:** Mixing biochar with compost before application enhances the nutrient content and microbial activity, leading to improved soil health.
2. **Dosage:**
    - The recommended biochar application rate varies based on soil type, crop requirements, and environmental conditions. Generally, application rates range from 1 to 20 tons per hectare. For degraded soils or those with low organic matter, higher doses may be beneficial, while fertile soils may require lower doses to avoid potential negative effects.

How Farmers Can Successfully Start with Biochar Application?

For farmers interested in using biochar, the following steps can guide a successful start:

1. **Assess Soil Needs:** Before applying biochar, conduct a soil test to determine its current condition and identify specific areas where biochar could be beneficial, such as improving nutrient retention or water-holding capacity.
2. **Choose the Right Biochar:** Select a biochar type that matches the needs of your soil and crops. Consider the feedstock, nutrient content, and pyrolysis process used in its production.
3. **Start with a Small Trial:** Begin by applying biochar to a small section of your field to observe its effects on soil health and crop productivity. This trial will help you determine the appropriate dosage and application method for your specific conditions.
4. **Combine with Other Soil Amendments:** To maximize the benefits of biochar, consider combining it with compost, manure, or fertilizers. This combination can enhance nutrient availability and improve overall soil health.
5. **Monitor and Adjust:** Regularly monitor soil and crop performance after biochar application. Adjust the application rate or method as needed based on the observed results and continue to refine your approach.

Significance in the Agriculture Sector

Biochar's significance in agriculture is multifaceted:

1. **Soil Fertility Enhancement:** Biochar improves soil fertility by increasing cation exchange capacity (CEC), thereby enhancing nutrient retention and availability. It also improves soil structure, water retention, and aeration, particularly beneficial for sandy or degraded soils.

2. **Greenhouse Gas Emission Reduction:** The incorporation of biochar into soils can reduce the emission of greenhouse gases such as nitrous oxide (N_2O) and methane (CH_4) from agricultural activities, contributing to climate change mitigation.
3. **Crop Yield Improvement:** Biochar application has been shown to enhance crop yields, especially in marginal soils. When combined with organic fertilizers, biochar creates a synergistic effect on soil health and plant growth.
4. **Waste Management:** Biochar production provides a valuable outlet for agricultural and forestry residues, converting waste biomass into a useful product and contributing to a circular economy.

Contribution to Soil Health and Carbon Sequestration

1. **Soil Health:**
   - **Physical Properties:** Biochar enhances soil porosity, promoting better water infiltration and retention, which is crucial in drought-prone areas. The improved soil structure also facilitates root growth and reduces soil compaction.
   - **Chemical Properties:** By increasing the soil's cation exchange capacity (CEC), biochar improves nutrient retention and availability, buffering soil pH to create favorable conditions for plant growth. The stable carbon structure of biochar also contributes to long-term soil fertility.
   - **Biological Properties:** Biochar serves as a habitat for beneficial soil microorganisms, supporting a healthy soil ecosystem. The porous structure of biochar provides shelter and a habitat for microbes, enhancing microbial activity and biodiversity in the soil.
2. **Carbon Sequestration:**
   - **Long-Term Carbon Storage:** Biochar sequesters carbon in soils for extended periods, potentially for centuries to millennia, reducing atmospheric CO_2 levels and contributing to climate change mitigation. The stable carbon in biochar is less prone to decomposition, making it an effective means of long-term carbon storage.
   - **Reduction of Greenhouse Gas Emissions:** The conversion of biomass into biochar stabilizes carbon that would otherwise be released during decomposition or burning. Additionally, biochar's ability to reduce the emissions of nitrous oxide (N_2O) and methane (CH_4) from soils further contributes to its role in greenhouse gas mitigation.

Economic Benefits

- **Improved Crop Yields:** The increase in crop productivity can offset the initial investment in biochar application.
- **Reduced Input Costs:** Enhanced nutrient retention and water efficiency may reduce the need for fertilizers and irrigation.
- **Long-Term Soil Health:** The enduring benefits of biochar on soil properties contribute to sustained agricultural productivity.

Research Findings and Policy initiatives

Numerous studies have demonstrated the positive impact of biochar on crop productivity. For instance, research conducted by Lehmann *et al.* (2011) found that biochar application increased maize yield by up to 140% in degraded soils, highlighting its potential in enhancing crop productivity, particularly in nutrient-poor soils. Similarly, a study by Jeffery *et al.* (2017) showed that biochar improved soil water retention, leading to better drought resistance in crops like wheat and soybeans. This improvement in soil properties directly correlated with increased yields. A meta-analysis by Liu *et al.* (2018) revealed that combining biochar with organic or inorganic fertilizers resulted in a 20-30% increase in crop yields compared to using fertilizers alone. The synergistic effects were attributed to improved nutrient availability and soil structure. Besides these, a research by Ding et al. (2016) demonstrated that biochar enhances soil microbial activity, leading to better nutrient cycling and increased plant growth. The study found that biochar application promoted the proliferation of beneficial microbes, contributing to soil health and productivity.

Governments worldwide are increasingly recognizing the potential of biochar in sustainable agriculture and climate change mitigation. For instance: The Indian government has shown interest in biochar as part of its sustainable agriculture initiatives. The Indian Council of Agricultural Research (ICAR) has been involved in research on biochar's application in different agro-climatic zones. Additionally, there are pilot projects in various states to test and promote biochar use among farmers. Similarly, the U.S. Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) have supported research and development of biochar for soil health improvement and carbon sequestration. Several states offer incentives for biochar production and application, reflecting its growing importance in sustainable agriculture. The European Union (EU) has also incorporated biochar into its strategies for sustainable agriculture and climate action, with several member states offering incentives for biochar production and application. The European Biochar Certificate (EBC) provides guidelines and standards for biochar production, ensuring quality and sustainability.

Challenges and Limitations

Despite its benefits, biochar application faces several challenges:

1. **Cost:** The production and application of biochar can be expensive, particularly for small-scale farmers. The high upfront costs associated with pyrolysis technology and transportation of biochar to fields may limit its widespread adoption.
2. **Variability in Performance:** The effectiveness of biochar can vary depending on the feedstock used, pyrolysis conditions, and soil type. This variability can lead to inconsistent results in crop productivity and soil health improvements.
3. **Knowledge and Awareness:** There is a lack of awareness and technical knowledge among farmers about the benefits and proper use of biochar. This gap hinders its adoption and integration into traditional farming practices.

Conclusion

Biochar offers a sustainable solution for improving soil health, enhancing agricultural productivity, and contributing to carbon sequestration. Its application in agriculture is gaining momentum, supported by research, government policies, and economic incentives. As global challenges such as climate change and food security intensify, biochar's role in sustainable agriculture is poised to expand, offering environmental and economic benefits for future generations. However, challenges such as cost, variability in performance, and the need for greater awareness must be addressed to fully realize the potential of biochar.

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ISSN : 2583-0910
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Article ID : 04/IX/07/0924

SAVING WILD LIFE: THE SYNERGY OF CONTROLLED BREEDING AND ASSISTED REPRODUCTION

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Abstract

The rapid decline in global biodiversity has driven conservationists to explore innovative strategies for preserving endangered species. Among these strategies, controlled breeding and assisted reproductive technologies (ART) have emerged as vital tools in wildlife conservation, enabling the management of genetic diversity, population size, and species survival. Controlled breeding involves the deliberate selection of individuals for mating to maintain or improve genetic traits and avoid inbreeding. Assisted reproductive technologies (ART), such as artificial insemination, in vitro fertilization, embryo transfer, and cryopreservation, support these efforts by enabling reproduction when natural breeding is not feasible. These techniques help to increase population sizes, preserve genetic material, and offer a lifeline to species at risk of extinction. Despite their potential, these methods pose ethical, logistical, and technical challenges, requiring careful consideration to ensure the long-term survival and adaptation of species in the wild.

Keywords : Breeding, wild life, Assisted reproductive technologies

Introduction

Controlled breeding and assisted reproduction in wildlife are techniques used to conserve endangered species, manage populations, and enhance genetic diversity. These methods, which have been extensively used in domestic animals and agriculture, are increasingly being adapted and applied to wildlife populations to address the challenges posed by habitat loss, climate change, and human encroachment.

Controlled breeding

Controlled breeding involves selecting specific animals within a population to mate based on their genetic traits, health, and lineage. The goal is to produce offspring that maintain or enhance the genetic diversity of the species, increase population size, and reduce the risk of inbreeding. It involves genetic and population management.

a. Genetic Management: Controlled breeding involves the deliberate selection of animals for mating, with the goal of managing the genetic diversity of a population. This process is crucial for species with small, isolated populations where inbreeding can lead to a loss of genetic diversity, reduced fitness, and increased susceptibility to diseases. Genetic management through controlled breeding helps to maintain a healthy gene pool, ensuring that the population can adapt to environmental changes and resist emerging threats.

- **Selective Breeding:** In wildlife conservation, selective breeding involves choosing individuals with specific desirable traits, such as disease resistance, physical robustness, or fertility, to produce offspring. This method can be used to enhance certain traits within a population while maintaining genetic diversity.

- **Cross-Breeding:** Cross-breeding between different populations or subspecies is sometimes necessary to introduce new genetic material, increasing genetic diversity and reducing the risks associated with inbreeding. This approach is particularly important for species with fragmented habitats, where populations are isolated and genetic exchange is limited.
- **Studbooks and Genetic Databases:** Many controlled breeding programs rely on detailed studbooks and genetic databases that track the lineage, health, and genetic makeup of individuals within a population. These tools enable conservationists to plan pairings that maximize genetic diversity and minimize the risk of inbreeding depression.

2. Population Management: Controlled breeding is also essential for managing population sizes in captive breeding programs and reintroduction efforts. By carefully controlling the number of offspring produced, conservationists can ensure that populations grow at sustainable rates, avoiding overcrowding in captivity or overwhelming ecosystems during reintroduction.

- **Breeding Programs:** Captive breeding programs are often established for species that are critically endangered or extinct in the wild. These programs aim to produce enough individuals to maintain a viable population in captivity, with the ultimate goal of reintroducing them into their natural habitats.
- **Reintroduction Projects:** Controlled breeding is a critical component of reintroduction projects, where animals bred in captivity are released into the wild. The genetic health of these reintroduced populations is carefully monitored to ensure that they can thrive and contribute to the long-term survival of the species.

Assisted Reproduction in Wildlife:

Assisted reproductive technologies (ART) are used to help animals reproduce when natural breeding is not possible or practical. This is especially useful for endangered species with small, fragmented populations.

1. Artificial Insemination (AI): Artificial insemination is a widely used assisted reproductive technology in wildlife conservation. It involves the collection of sperm from a male, which is then manually inserted into the female's reproductive tract. AI is particularly useful for species with low natural breeding success, males that are geographically distant, or when preserving the genetic material of deceased individuals.

- **Semen Collection and Preservation:** Sperm can be collected through various methods, including electroejaculation or manual collection. Once collected, it can be used fresh or cryopreserved for future use, allowing genetic material to be stored and transported over long distances.
- **Applications in Conservation:** AI has been successfully used in the conservation of several species, including elep
- hants, rhinos, and big cats. This technique allows for the genetic contribution of males that may not be able to breed naturally, either due to health issues, behavioral challenges, or geographical separation.

2. In Vitro Fertilization (IVF): In vitro fertilization involves the extraction of eggs from a female, which are then fertilized with sperm in a laboratory setting. The resulting embryos are cultured and then implanted into the female's uterus or a surrogate. IVF is particularly valuable for species with fertility issues or those that produce few offspring naturally.

- **Egg Collection and Embryo Culture:** Eggs are collected through minimally invasive procedures and fertilized in a controlled environment. The embryos are then monitored and cultured until they are ready for implantation.
- **Embryo Transfer:** IVF often leads to multiple embryos, which can be implanted into multiple surrogates or stored for future use. Embryo transfer has been used in species like cheetahs, where natural reproduction rates are low.

3. Embryo Transfer and Surrogacy: Embryo transfer involves implanting embryos, either created through IVF or collected from a donor female, into a surrogate mother. This technique allows for the propagation of endangered species even when the natural mother is unable to carry a pregnancy to term.

- **Surrogacy in Conservation:** Surrogacy has been used in species such as the giant panda, where the natural mother may be unable to raise offspring. The use of a surrogate allows for the continuation of the species without risking the health of the mother.

4. Cryopreservation: Cryopreservation is the process of freezing sperm, eggs, embryos, or even tissue samples for long-term storage. This technology is crucial for maintaining genetic diversity, particularly for species with dwindling populations. Cryopreserved material can be thawed and used in ART at any time, providing a genetic reservoir for future conservation efforts.

- **Gene Banks:** Many conservation organizations maintain gene banks, where cryopreserved material from endangered species is stored. These gene banks serve as a safeguard against extinction, allowing for the potential reintroduction of genetic material into wild populations.

5. Cloning: Cloning, while controversial, is a method of assisted reproduction where a genetically identical copy of an individual is created from its DNA. This technology has been explored as a last resort for critically endangered species with very few individuals remaining.

- **Somatic Cell Nuclear Transfer (SCNT):** The most common cloning technique, SCNT, involves transferring the nucleus of a somatic cell into an egg cell from which the nucleus has been removed. The resulting embryo is then implanted into a surrogate mother. Cloning has been successfully used in some species, such as the banteng and the Przewalski's horse, but it remains a complex and ethically debated method.

Challenges and Considerations

Controlled breeding and assisted reproduction in wildlife face numerous challenges, including managing genetic diversity to avoid inbreeding and genetic drift, adapting ART techniques to the unique reproductive needs of wildlife, and addressing the ethical concerns associated with invasive procedures and human intervention. Additionally, the resource-intensive nature of ART, variable success rates, and high costs complicate its application. Animals bred in captivity may struggle to adapt to wild conditions, posing risks to both their survival and integration with existing populations. Ensuring the long-term sustainability and ecological balance of these efforts requires careful planning and ongoing monitoring.

Case Studies

- **Giant Pandas:** Controlled breeding and artificial insemination have been widely used in panda conservation programs, with notable success in increasing the population.

- **Cheetahs:** Due to low genetic diversity, ART has been employed to enhance breeding programs, although success rates remain variable.
- **Northern White Rhino:** With only two females remaining, ART and cloning are being explored as potential methods to save the species from extinction.

Conclusion

Controlled breeding and assisted reproduction are powerful tools in the fight against biodiversity loss. While these techniques offer significant potential for preserving endangered species and enhancing genetic diversity, they also present complex challenges that require careful consideration. The continued advancement and refinement of these methods, coupled with ethical and ecological awareness, will be essential for their successful application in wildlife conservation. As conservationists strive to save species on the brink of extinction, controlled breeding and ART will play an increasingly important role in ensuring the survival of our planet's most vulnerable wildlife.

Acknowledgement

The ChatGPT, an AI-powered chatbot (https://www.openai.com/chatgpt) was used for language modulation

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/08/0924

DISCOVERING DAPHNIA: UNVEILING THE SECRETS OF THE WATER FLEA

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Abstract

The ornamental fish industry is experiencing growth by increasing popularity of aquarium leading to a high demand for high quality live feeds, particularly for fish larvae during their early developmental stages. Daphnia, commonly known as water fleas, are important due to their rich nutritional profile and suitability as live food. They are essential for improving the growth and immune of ornamental fish larvae by providing crucial nutrients often lacking in formulated feeds. This article explores the aspects of Daphnia including their life cycle, biology, nutritional value and culture techniques. Their identification characters (size, body structure, and heart rate), life cycle and their nutritional content (high in proteins and lipids) are highlighted. This article also addresses the constraints in Daphnia culture, emphasizing the need for optimal feeding conditions and impact of dietary composition on their nutritional quality. Understanding these aspects is crucial for improving larviculture practices and ensuring the successful growth of ornamental fish.

Key words : Daphnia, Feeding, Live feed and Life cycle

Introduction

The ornamental fish industry, encompassing the breeding, rearing, and sale of aquarium fish is a thriving global market. With the increasing popularity of aquariums in homes, offices and public places, there is a rising demand for high quality live feeds to ensure the health and growth of ornamental fish, particularly during their early developmental stages. As live feed is crucial for the optimal growth and survival of fish larvae providing essential nutrients that are not adequately supplied by formulated feeds. Approximately 5300 freshwater ornamental fish species and approximately 2500 marine ornamental fish species are traded worldwide. One of the most significant difficulties faced by farmers in larviculture is feeding larvae during weaning stage. After yolk absorption, larvae undergo a transition from endogenous to exogenous feeding, which does not benefit from a well-developed gastrointestinal tract to efficiently digest the formulated diets (Yufera and Darias, 2007). Successful larviculture depends on the feeding nature and nutritional requirements of the larvae being cultured (Mejri *et al.*, 2021).

Daphnia, commonly known as "water fleas" are small planktonic crustaceans belonging to Order Cladocera and family Daphniidae. It is found in various freshwater environments such as ponds, lakes and streams followed by brackish water and marine habitats. There are more than 100 identified Daphnia species, all of them have a similar body structure which includes a relatively large head with a single compound eye and a body enclosed in a shell resembling a bivalve. This shell is made up of a polysaccharide called chitin. The most commonly found species are *Daphnia pulex* (small and most common) and *D. magna* (large). These tiny creatures play an important role in aquatic ecosystems. As they are fleshy and non-throny serves as a primary food source for many fish and other aquatic organisms. They are rich in proteins, lipids and essential vitamins making them highly nutritious. The health and reproduction of Daphnia depends on the energy used for identification and location of food and feeding.

Biology of Daphnia

Daphnia is a group of filtering organisms that mainly consumes microalgae, but they also consume bacteria and detritus so their culture is easier. The brood pouch is on the dorsal side of the female where the eggs and embryos develop. It is completely closed while Moina have an open pouch. Daphnia periodically shed their outer shell by molting. Like other cladocerans, Daphnia exhibits three different reproductive states i.e., Parthenogenetic female (PF), sexual female (SF) and male (M). Under favourable conditions, parthenogenetic (asexual) reproduction predominates, resulting in rapid population growth. However, when environmental conditions worsen, Daphnia switches from asexual to sexual reproduction. This shift leads to the production of resting eggs, which are capable of withstanding harsh conditions and are formed through mating between sexual females and males. This reproduction is an adaptation to their external environment, the parthenogenetic reproduction can lead to the quick population expansion while the sexual reproduction can enable the survival through extreme environmental challenges, ensuring the population existence. The triggers for the transition from asexual to sexual reproduction in Daphnia populations included food scarcity, oxygen depletion and high population density. The occurrence of male Daphnia could be induced by juvenile hormone analogs (Tatarazako *et al*., 2003).

Identification characteristics

The size of the Daphnia ranges about 0.2 – 6 mm (0.01-0.24 in) long and it is divided into segments. It has large head with rostrum. Paired eyes are fused into one. Five pairs of leaf like feet present on thorax. In most of the species, body is covered with carapace. In many species, the carapace is transparent, so they make excellent subjects for the microscope. The average heart rate is about 180 bpm under normal conditions.

Life cycle of Daphnia

The life cycle of Daphnia is much shorter, not exceeding 5-6 months. It can reproduce both sexually and asexually. During this process, the female produces amictic eggs (a clutch of parthenogenetic eggs) and keeps them in brood pouch. After about 3 days, the young Daphnia are released directly from the mother brood pouch. The offspring closely resemble their mother, but they do not have a brood pouch. After undergoing six moltings, the young daphnia attains maturity and produce the egg for first time, a stage know as primipara. Typically, it takes 5-10 days to reach this stage, although the duration is highly dependent on temperature. The adult daphnia release eggs every 3-4 days until they die. Under captive conditions, the lifespan of Daphnia is about 2 months.

Nutritional aspects of Daphnia

Daphnia have a protein content of about 50% dry weight and a fat content of 20- 27% for adults (juveniles – 4-6 %). The protein content of *D. magna* reaches 30%- 70% with a calorie level of 333.7 cal (El-Feky & Abo-Taleb, 2020). The nutritional content of *D. magna* varies depending on the nutritional composition of the feed given (Cheban *et al*., 2017). Natural food Daphnia sp. in wet conditions it has a protein content of 4%, fat 0.54%, carbohydrates 0.67% and ash 0.15% (Maulidiyanti *et. al*., 2015). The nutritional content of *D. magna* depends mainly on the culture medium, as this medium impacts the growth of the phytoplankton which serves as its food source.

According to Brett *et al*., 2006, diet predominantly influences the fatty acid content in Daphnia. However, irrespective of diet, Daphnia also retains some consistent features of their fatty acid profiles.

Daphnia grow rapidly and are relatively lean, allowing them to quickly replace their lipid reserves with new dietary lipids in a short period of time. According to Muller-Navarra (2006), Daphnia species that consume cyanobacteria rich in saturated fatty acids typically have only about half the amount of these fatty acids compared to their diet. This indicates that enrichment alone is not a fully effective method for enhancing their nutritional value. It is more beneficial to provide a combination of live organisms and an appropriate artificial diet to meet their nutritional needs of the larvae. On the other hand, daphnia are good sources of various digestive enzymes such as proteases, amylases, lipases and cellulase. These enzymes aid in the digestion of developing larvae through the exoenzymes present in their gut (Cheban *et al*., 2017).

Biochemical parameters	% of composition
Protein	45-70%
Lipid	11-27%
Carbohydrate	15-20%
Moisture	85-95%

Constraints in the culture of Daphnia

The main constraint in the culture of daphnia is the contamination with rotifers. These reduce the daphnia production by competing them with space and food. These rotifers can be easily removed by using an appropriate mesh sized sieve, which allows rotifer to pass through sieve and retain the daphnia based on their size differences. Another problem is the invasion of the parasite *Pasteuria ramose.* This bacterial parasite infects daphnia, significantly impacting their health and population dynamics. During this infection, the size of the daphnia increases significantly and the lifespan is also reduced.

Culture techniques of Daphnia

Daphnia can be cultured using different methods such as Batch culture, semi continuous culture and it can also be cultured in tanks or containers, ponds etc. Batch culture is a type of continuous culture in which daphnia is constantly produced and harvested. In semi continuous culture, the culture duration is 1-2 months or more. It is done by doing partial harvest daily.

Optimum water quality parameters for daphnia culture

Parameters	Optimum range
Temperature	18-24°C
Dissolved oxygen	2-5 mg/l
Hardness	250 mg/l
pH	6.5-8.5
Ammonia	<0.2 mg/l
Light	10–20-hour photo period

Harvesting

Daphnia can be very easily harvested using mesh nets of range100-200 µm as they mostly swim in the surface of water. In semi-continuous culture, 15-30% of the population is allowed to harvest partially.

Conclusion

Daphnia are essential for the ornamental fish industry particularly for feeding fish larvae. Their high protein and lipid content make them ideal live feed. It can reproduce rapidly and adapt to various conditions, making them easy to cultivate. However, successful cultivation requires proper management of their diet and environment parameters. In summary, Daphnia are vital for aquaculture, but ongoing research is needed to optimise their cultivation and nutritional value, ensuring sustainable growth in the ornamental fish industry.

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ISSN : 2583-0910
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Peer reviewed monthly newsletter

Article ID : 04/IX/09/0924

DEBT, DESPAIR, AND DEATH: THE TRAGIC REALITY OF INDIAN FARMING

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Abstract
With more than 50% of the workforce engaged in agriculture, the issue of farmer suicides in India has become a major concern. Between 1995 and 2006, the country experienced a staggering 166,000 farmer suicides, with an annual peak of 18,000 cases. Several complex factors contributed to this crisis, including increasing debt worsened by the lack of official credit sources and the rise in high-interest loans from non-institutional lenders. Neoliberal policies have also worsened the agrarian problem by reducing the GDP contribution of the agricultural sector while maintaining a large workforce dependent on it. Inadequate irrigation infrastructure further exacerbates farmers' vulnerabilities, particularly in rain-deficient areas, impacting agricultural yields and stable revenue. The situation disproportionately affects those who grow cash crops or marginal farmers, and there are concerns about state-sponsored subsidies potentially contributing to the issue. It is essential to implement comprehensive policy interventions that prioritize revitalizing the agricultural sector and protecting the livelihoods and well-being of India's farming community to address this complex problem.

Keywords: Agrarian Crisis, Crop failure, Debt, Factors, Farmer suicide, Irrigation

Introduction

The primary economic sector, which ensures our country's food and nutrition security, faces a critical issue: rural distress. One of the most alarming consequences of agrarian hardship is the prevalence of farmer suicides.

Government statistics reveal that between 1995 and 2006, approximately 166,304 farmers in India took their own lives, averaging around 16,000 suicides per year. At its peak, the annual figure reached 18,000 farmer suicides (Nagaraj, 2014).

Breaking down the NCRB figures, Nagaraj (Nagaraj K, 2014) estimates that as of 2001, the overall suicide rate for farmers across India was 15.8/100,000 people, 50% higher than the general population rate and that this has been increasing at a rate above that of the general population.

Based on data from the National Crime Records Bureau (NRCB), (Nagraj, 2008) found that, between 1997 and 2006, farm suicides accounted for one in seven suicides nationwide. The observation also noted that male farmers constituted the majority of these suicides, with farm-related suicides representing one in every five male suicides.

Factors Causing Farmer's Suicide

Debt-Induced Tragedies Among Farmers in Vidarbha

In Maharashtra's Vidarbha district, farmers identified debt as the foremost reason for farmer suicides, ranking it higher than factors such as addictions, adverse weather conditions, and price concerns, among others (Dongre. *et al.*, 2018). Unpaid debts have been linked to suicide deaths, according to the findings of two further investigations (Gruere. *et al.*, 2011; Mishra. 2006).

Decline of Agricultural Credit and Its Impact on Farmers

After 1989, there was a notable decrease in the proportion of bank loans directed towards agriculture, with estimates dropping from 20% to 12% by 1994 (Sadanandan. 2014). This percentage had been cut in half by the 2000s, and farmers were receiving even less—that is, only 8%—of the total (Sadanandan 2014). There is more to the drop in bank loans to agriculture than just a decline in the sector's percentage of the nation's GDP. Instead, it represents a decline in official funding sources, leading to a greater dependence on loans from non-institutional providers such as neighbourhood moneylenders, who charge much higher interest rates (Sadanandan. 2014; Mishra. 2006; Dongre, *et al.,* 2012; Sarangi *et al*., 2010).

Numerous research has demonstrated the crucial role that non-institutional sources play in enabling farmers to obtain credit, and three of those studies discovered that farmers who committed suicide were more likely than controls to have debt from non-institutional sources (Mishra. 2006; Kale. 2011; Gedela 2008).

Impact of Irrigation Deficits on Farmer Suicides

According to Kale, over 85% of the land in some of the most severely affected regions of Vidarbha is rain-fed, which makes farmers especially vulnerable to sharp fluctuations in yields and, consequently, returns.

Apart from diminishing returns and potential crop failures, insufficient irrigation could also contribute to the increasing debt burden. Banks might be reluctant to extend loans to farmers lacking irrigation systems due to the uncertainty surrounding the return on their investment. Additionally, alongside debt and cash crop cultivation, there exists a notable correlation between the prevalence of marginal farmers in different states and the suicide rate (Kennedy *et al*., 2014).

Unintended Consequences of Substantial Grants on Farmer Suicides:

Another factor potentially influencing farmer suicide rates is the significant grants provided to the families of farmers who die by suicide in various states (Divya. 2015). There have been suggestions that such grants could inadvertently incentivize suicides (Gruere *et al*., 2011; Herring .2008).

Conclusion

Comprehensive legislative initiatives are urgently required to tackle the underlying factors contributing to agricultural distress, particularly given India's alarmingly high rate of farmer suicides. Effective strategies include diversifying sources of income for farmers, enhancing irrigation infrastructure to enhance agrarian resilience, and reducing farmer indebtedness by facilitating access to low-cost financing. Additionally, it's crucial to reevaluate the impact of neoliberal policies on agricultural sustainability. By prioritizing the well-being of farmers and revitalizing the agricultural sector, Indian authorities can mitigate the profound impacts of farmer suicides and secure the long-term prosperity of farming communities.

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ISSN : 2583-0910
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monthly newsletter

Article ID : 04/IX/10/0924

THE ROLE OF COOPERATIVES IN ENHANCING LIVESTOCK FARMER INCOMES IN INDIA

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Introduction

In India, agriculture is the backbone of the economy, and livestock farming is a significant component of this sector. Livestock contributes around 4.11% to the national GDP and provides livelihood to two-thirds of the rural community. However, despite its importance, livestock farmers, particularly smallholders, often struggle with low incomes due to various challenges, including market access, lack of credit, and inadequate infrastructure. Cooperatives have emerged as a powerful tool to address these challenges and enhance the incomes of livestock farmers.

The Concept of Cooperatives

Cooperatives are voluntary organizations formed by individuals with common economic, social, and cultural needs. These organizations operate on the principles of self-help, democracy, equality, and solidarity. In the context of livestock farming, cooperatives can take various forms, including dairy cooperatives, poultry cooperatives, and meat cooperatives. These cooperatives aim to provide better market access, improve bargaining power, offer credit facilities, and ensure fair prices for their members.

Historical Background of Cooperatives in India

The cooperative movement in India dates back to the early 20th century. The establishment of the first cooperative society in 1904 marked the beginning of this movement. Over the years, the cooperative sector has expanded significantly, encompassing various aspects of agriculture, including livestock farming. The success of dairy cooperatives, particularly the Amul model, has been a testament to the potential of cooperatives in transforming the livelihoods of livestock farmers.

Enhancing Market Access

One of the primary challenges faced by livestock farmers is limited market access. Smallholder farmers often lack the resources and knowledge to reach larger markets, resulting in low prices for their produce. Cooperatives play a crucial role in bridging this gap. By aggregating the produce of their members, cooperatives can achieve economies of scale, enabling them to access larger and more lucrative markets.

For instance, dairy cooperatives like Amul have established robust supply chains, connecting small dairy farmers to urban markets. This not only ensures a steady market for the farmers' produce but also fetches them better prices. Moreover, cooperatives often engage in branding and marketing activities, further enhancing the value of their members' produce.

Improving Bargaining Power

Individually, smallholder livestock farmers have limited bargaining power, making them vulnerable to exploitation by middlemen and traders. Cooperatives empower farmers by providing a collective bargaining platform. By negotiating as a group, farmers can secure better prices for their produce, ensuring fair compensation for their efforts.

A notable example is the Karnataka Cooperative Milk Producers Federation (KMF), which has been instrumental in enhancing the bargaining power of dairy farmers in the state. KMF's collective approach has resulted in better pricing, timely payments, and a more transparent market for its members.

Access to Credit and Financial Services

Access to credit is a significant barrier for many livestock farmers. Traditional financial institutions often hesitate to extend credit to smallholder farmers due to perceived risks and lack of collateral. Cooperatives address this issue by providing their members with easier access to credit and other financial services.

Many cooperatives have established their own credit societies, offering low-interest loans and other financial products to their members. This financial support enables farmers to invest in better livestock, feed, and infrastructure, ultimately enhancing their productivity and income. For instance, the National Cooperative Development Corporation (NCDC) provides financial assistance to cooperatives for various development projects, including livestock farming.

Infrastructure and Technical Support

Inadequate infrastructure and lack of technical knowledge are significant impediments to the growth of livestock farming in India. Cooperatives play a vital role in addressing these issues by providing necessary infrastructure and technical support to their members.

Dairy cooperatives, for example, often establish milk collection centers, cold storage facilities, and processing plants, ensuring that the produce is handled efficiently and reaches the market in optimal condition. Additionally, cooperatives organize training programs and workshops to educate farmers on best practices in animal husbandry, disease management, and feed optimization. The National Dairy Development Board (NDDB) has been at the forefront of such initiatives, working closely with cooperatives to enhance the skills and knowledge of dairy farmers.

Value Addition and Diversification

Value addition and diversification are essential strategies for increasing the income of livestock farmers. Cooperatives play a pivotal role in promoting these strategies by facilitating the processing and marketing of value-added products. By processing raw produce into products such as cheese, yogurt, and leather goods, cooperatives can fetch higher prices and open new revenue streams for their members.

For example, the Lijjat Papad cooperative has successfully diversified its product range, including dairy products, thus providing its members with additional income opportunities. Similarly, poultry cooperatives have ventured into processing and packaging, ensuring that farmers receive a fair share of the profits from value-added products.

Social and Economic Empowerment

Beyond economic benefits, cooperatives also contribute to the social and economic empowerment of livestock farmers. By fostering a sense of community and mutual support, cooperatives help build social capital among their members. This collective strength is particularly beneficial for marginalized groups, including women and smallholder farmers, who often face discrimination and limited opportunities.

Women, in particular, have benefited significantly from cooperative membership. Women's dairy cooperatives, such as the Self-Employed Women's Association (SEWA) in Gujarat, have empowered women by providing them with income-generating opportunities, enhancing their decision-making power, and improving their overall social status.

Challenges and the Way Forward

Despite their numerous benefits, cooperatives in the livestock sector face several challenges. These include bureaucratic hurdles, lack of professional management, and competition from private players. Additionally, not all cooperatives are equally successful, and some suffer from issues such as mismanagement and corruption.

To address these challenges and unlock the full potential of cooperatives, several measures can be taken:

- **Capacity Building**: Investing in the training and capacity building of cooperative leaders and members to improve management practices and ensure transparency.
- **Policy Support**: Strengthening policy support for cooperatives, including simplifying regulatory frameworks and providing incentives for cooperative formation and growth.
- **Technology Integration**: Leveraging technology to improve the efficiency of cooperatives, including digital platforms for market access, financial services, and information dissemination.
- **Public-Private Partnerships**: Encouraging partnerships between cooperatives and private enterprises to bring in expertise, investment, and market linkages.

Conclusion

Cooperatives have demonstrated their potential to enhance the incomes of livestock farmers in India by providing better market access, improving bargaining power, offering credit facilities, and ensuring technical support. The success stories of dairy cooperatives like Amul and KMF highlight the transformative impact of cooperatives on the livelihoods of farmers. However, to fully realize this potential, concerted efforts are needed to address existing challenges and foster a more supportive environment for cooperatives. With the right support and initiatives, cooperatives can continue to play a pivotal role in enhancing the incomes and improving the lives of livestock farmers across India.

Acknowledgement : I acknowledge the use of ChatGPT, an AI-powered chatbot (https://www.openai.com/chatgpt) for language modulation. The images used in this article are collected from the various internet sources.

ISSN : 2583-0910
Agri-India TODAY
visit us at www.agriindiatoday.in

Peer reviewed
monthly newsletter

Article ID : 04/IX/11/0924

CHANGING FACE OF BALANCED FERTILIZATION

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Abstract

Indian Agriculture is operating at negative nutrient balance of about 10 million ton of NPK resulting continuous mining of soils nutrient capital in respect of potassium, secondary and micronutrients. There is considerable disparity in the use of fertilizers in different states, in many cases too little, for instance in the north east states and hilly regions of north west, is a major constraint to crop productivity. There is also considerable imbalance in the use of nutrients; often too much of nitrogen and too little phosphorus and potassium are applied. The use of secondary and micronutrients is altogether missing and their availability to the farmers is also a major constraint. It is critical that nutrient balance, including the ready availability of needed fertilizer nutrients, be an objective rather than a casualty of policy decisions. In order to meet all objectives of sustainable agriculture…increased food, feed and fiber, the profitability, efficiency of input use and an appropriate concern for the environment…a balance of adequate levels of nutrients is the key component. Practicing balanced and efficient fertilizer use to correct all existing nutrient deficiencies at field scale and decide nutrient doses to achieve set yield target and simultaneously by adopting best management practices is the need of the day which is being discussed in this paper.

Introduction

India can look back proudly over 35 years of unprecedented growth in food production. An ample supply of cheap food was a major factor underpinning the very rapid economic growth in the country. However, most of the rapid increase in this period came from a very narrow production base, namely rice grown on irrigated lowlands and wheat grown on nonacidic soils in cooler or drier regions. The increased yields of irrigated rice and wheat was brought about, in part, by the greatly increased use of nitrogen and, to a lesser extent, phosphatic fertilizers. Today, the increases in food production obtained during the last over 50 years are often not being sustained. Where inputs are very small, or nonexistent, soil fertility is declining and even where larger inputs are used, they are often unbalanced so that the return per unit of input is decreasing. Thus, food security in India is once again a matter of concern, not least because it could threaten future economic growth. Population growth is still the major factor controlling food demand. Not only will the demand for food increase but there is a rapidly changing demand for a wider range of foods as the economic situation in India further improves. To minimize imports, a greater variety of extra food will have to be produced locally and the only underused resource is the rainfed uplands. But bringing them into profitable production will not be achieved readily. In India not only are the soil resources of cultivated lands are depleted, but many of the soils are currently farmed by poor farmers who lack the financial resources to undertake the necessary measures to improve the productive capacity of the soils. The threat to food production in India, therefore, is the degradation of presently fertile soils and of already infertile degraded ones. This paper aims at highlighting the issues and strategies to adopt balanced crop fertilization practices to ensure food, nutrition and environment security.

Issues

For the past several years, it is being mentioned that Indian agriculture is operating at an annual nutrient deficit of about 10 million tons (mt) of $N+P_2O_5+K_2O$. This is essentially due to nutrient removals far in excess of nutrient additions. Greatest blame for soil nutrient depletion rests with unbalanced fertilizer application consisting of large N applications without matching amount of other nutrients. What the farmers have been, in fact, doing in many areas, year after year, is to use N (urea) as a shovel to mine the soil reserves of other nutrients, particularly K, P, S and in several cases micronutrients as well. It is the depletion of nutrients, which has resulted in large increase in crop response to P and K with the passage of time. The real alarming situation is that in many cases, even the recommended application of fertilizers results in soil nutrient depletion, because they turn out to be sub-optional for supporting high-yielding intensive cropping systems. An ICAR committee headed by Dr. J.S. Kanwar, India's most well-known soil scientist has this to say based on results of long term fertilizer experiments: "Serious note should be taken of the damage which unbalanced fertilizer use, specially that of nitrogenous fertilizers alone without adequate input of P and K has done. The fertilizer policies which encourage the use of only one type of fertilizer particularly N alone can lead to decline in productivity and reduction in response to N as was observed in all the experiments in this project". Besides this, continuous mining of secondary and micronutrients has depleted nutrient reserves of soil. Apparently, in India, the main environmental hazard is the depletion (mining) of soil nutrients due to inadequate replenishment rather than pollution due to their excessive use. Depleting a soil of its nutrient reserves is also degradation of the environment while improving soil fertility is part and parcel of improving the natural resource base, and hence, the environment itself.

During the recent past, the productivity of rice–wheat cropping system has started stagnating or even declining in certain areas due to continuous depletion of native nutrient reserves causing multi-nutrient deficiencies, and consequent decline in factor productivity of applied nutrients. To compensate the effect of declining factor productivity farmers have started applying greater doses of N than the recommended ones. Such indiscriminate use of N has further worsen the nutrient imbalance in soil-plant systems, besides increasing the pest incidence, cost of production and environmental problems. Studies indicate that crop productivity can be sustained with balanced fertilization, including secondary and micronutrients. In the studies initiated by the IPNI, India Program PPI/PPIC-India Program it was possible to harvest 8-10 ton/ha rice yield and 5-7 ton of wheat with Site Specific Nutrient Management (SSNM). On the other hand, the annual productivity of rice or wheat in these experiments on yield maximization conducted under All India Coordinated Cropping Systems Research Project was hardly 6 t/ha. The advantage of yield maximization through SSNM is the land saving which provides opportunities for diversification of agriculture without sacrificing total food production. A rice-wheat cropping sequence at moderate yield level of 10 t/ha, removes nearly 280 Kg N, 30 Kg P and 300 Kg K from the soil. Evidently, even with the recommended rate of fertilization, a negative nutrient balance particularly of K is being noticed. To reverse the trend of declining crop yields, national government should develop policies which should provide the farmers with the required technical and institutional support to break the barriers of stagnation in food production and fertilizer consumption.

The fertilizer consumption and so the crop production trends particularly of rice and wheat, the two main staple food of India have been showing stagnation or decline in most of the Indo- Gangetic plains where rice- wheat cropping system is being continuously adopted. The crop production seems to be stagnant mainly because of inadequate and unbalanced use of fertilizers depending upon farmers' own decision and monetary convenience, thus causing depletion of the soil's nutrient reserves. Obviously, our agriculture is N or N+P driven and in consequence a lot of K mining has taken place. The crops in each and every part of the country are showing K deficiency symptoms and merely because of ignorance, these problems remain unattended with consequences of severe depletion of nutrient thus increasing the magnitude of nutrient deficiency and in consequence, the farmers are compelled to loose yield, produce quality and finally their profits. If this happens on a continuing basis, the cost of crop production is bound to decrease because of low factor productivity and the agriculture itself cannot be sustainable. Given below are the major factors responsible for stagnation in fertilizer consumption food production.

Poor Soil Fertility - A Major Constraint : Nitrogen deficiency in Indian soils is almost universal so the medium-high yields cannot be obtained anywhere without N application. Phosphorus deficiencies are not far behind those of N as in 95 per cent districts, the P fertility is either low or medium. This is alarming because P is the backbone of balanced fertilizer use. The results of thousands of experiments conducted by ICAR on farmers' fields show that quite often profitable yield increases to applied P are obtained on soils which are traditionally rated as high in available P. Therefore, soil fertility limits them-selves need a fresh look. Regarding K, it was earlier believed that there was no need of K application in alluvial soils of Indo-Gangetic plain region, as these soils were considered to be rich in potassium. However, the results of the research evidenced that depletion of soil K seemed to be general cause of yield decline in 23 rice-wheat long-term experiments in the Indo-Gangetic plains. This situation has emerged because of increased productivity and production of rice- wheat system with increased use of N and P without or with negligible input of K which in turn caused depletion in the soil's K reserves. The K supplying capacity of the soils which may be high for a yield of 3 t ha^{-1} is actully low K for a yield of 6 t ha^{-1}. Similar observations have been on record in other cropping systems in irrigated regions. Sulphur deficiency is an important problem in many states and soils in large number of districts all over the country are considered to be suffering from S deficiency to varying extent. Indications are that S deficiencies will become even more important in coming years and in such areas the balanced fertilizer use will have to include S along with NPK application. With intensive cultivation of high yielding varieties deficiency of micronutrients became a major cause of declining productivity in many soils. Among micronutrients, zinc deficiency was found to be the most common problem. Fifty per cent of the Indian soils are deficient in zinc and about 20% soils have hidden hunger. Next to zinc, boron deficiency is wide spread in many soils leading to low crop yields. Of the 36825 surface samples analyzed, 33 per cent soil samples were found to be deficient in available boron. Manganese deficiency is also becoming one the constraints in achieving targeted productivity.

Nutrient Supply through Fertilizers: Inadequate and Unbalanced: Despite phenomenal rise in fertilizer use, the intensity of fertilizer use, which is a better measure of adequacy of fertilizer application across crops and regions, is not satisfactory. Nutrient additions generally fall short of

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

requirements. India's position is not very comfortable as is its ranking in total fertilizer consumption. Even in South Asia, India uses far less fertilizer ha^{-1} year^{-1} than Sri Lanka, Bangladesh and Pakistan and in most cases, soil nutrient balances in India are negative with an annual deficit of about 10 mt $N+P_2O_5+K_2O$ between crop removal and fertilizer application. Nutrient wise apportioning of the NPK consumption ha^{-1} year^{-1} does not indicate match with the crop requirements. Precariously, poised K use with respect to N and P has been in existence for the last over 60 years. Although one may justify less emphasis on K management in terms of previous soil fertility scenario, but over the years that scenario has changed and its continuous mining is bound to flare up in intensity. Indeed, changing NPK balance is quite undesirable and its influence on sustainable growth in productivity of crops is disturbing. Generally, inclusion of K in fertilizer package generally improves crop productivity. Implications of inadequate and unbalanced use of fertilizers are: (1) More acute nutrient deficiencies, (2) More widespread nutrient deficiencies (3) Fall in fertilizer use efficiency and factor productivity and farmers profit from fertilizer use and other investments (4) Weakening the foundation of high-yielding sustainable farming and (5) Very high remedial cost of building up depleted soils.

Even though India is the third largest fertilizer user, the consumption is highly concentrated in certain areas and large areas receive very little fertilizer. The average rate of application is also indicative of few well-fertilized areas and large areas receiving very small rates of application. There is thus a large untapped potential. Its exploitation requires an area-wise constraint analysis because if the fertilizer use pattern is highly skewed, there must be reasons for this. Apart from this, there is little resemblance between the pattern of NPK removal by crops and their consumption through fertilizers with N dominating nutrient additions and K dominating removals (**Fig. 1**).

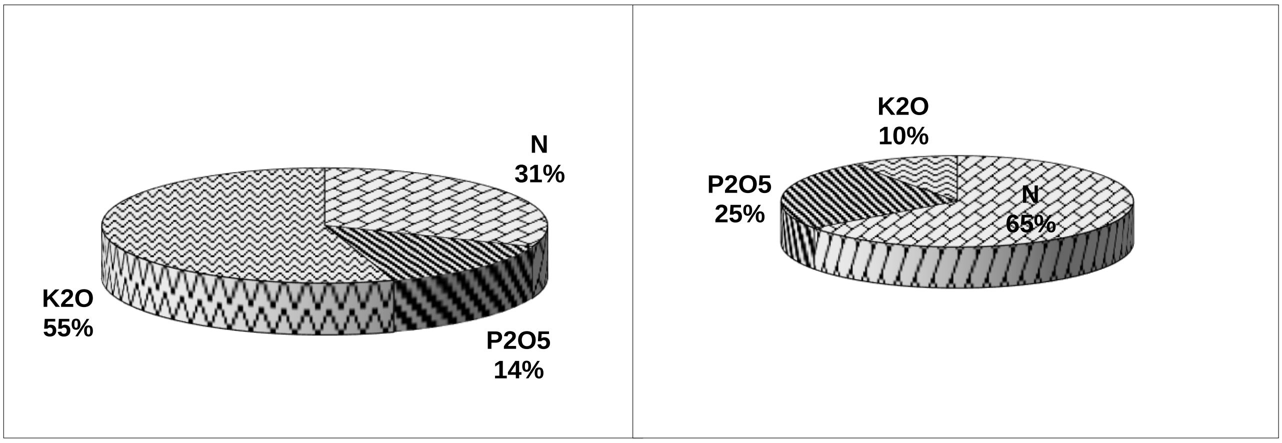

Fig 1: The contrasting pattern of nutrient removal (left) and nutrient consumption in Indian agriculture (right)

Regional Disparities : There is disparity in consumption ratio of NPK which is more pronounced in the northern states indicating highly imbalanced use of fertilizers. There are a lot of disparities in the fertilizer consumption pattern both between and within the eco-regions in India. Average consumption of the plant nutrients both in the western and eastern zones are far below the national average although these states have high potential of using more mineral fertilizer. Greatest degree of N: P imbalance is seen in the case of Punjab and Haryana, Uttar Pradesh and Bihar. Among geographical zones, N:P ratios are relatively wider in the North and East zones as compared to South and West. However, N:K ratios are relatively wider in the North and West zones as compared to South and East.

Unrealistic Fertilizer Consumption Projection : Fertilizer (Nutrient) consumption as being projected by the states is based on the past growth rate in fertilizer consumption and not as per need of the state/country for achieving higher production targets and as such, the quantities of N, P_2O_5 and K_2O projected are highly imbalanced as were in the past. This kind of fertilizer consumption will lead to poor nutrient use efficiency and low factor productivity, depletion in the soil's nutrient reserve and thus increased environmental problem, finally low yield, and poor farmers' profit. To maintain the Government's desired ratio of at least 4:2:1, the K_2O consumption needs to be significantly enhanced.

Crop wise Nutrient Consumption Pattern : Crop wise fertilizer consumption pattern clearly indicate that nutrient consumption in crops grown in India is not only inadequate but unbalanced too. The most important fertilizer using crops are rice, wheat, cotton, sugarcane, rapeseed mustard, groundnut and sorghum with a total share of about 55%. Seventy percent or more area under rice, wheat, sugarcane, cotton, groundnut, rapeseed-mustard was estimated to be fertilized. Among major field crops, sugarcane was the most intensively fertilized followed by wheat, rice and cotton and rapeseed mustard. Apparently, consumption of potash in all the crops is much lower than that needed by the crops for desired yield goals and in crops like millet, pulses and oil seeds , it is negligible.

Losing Yield: Nutrient Mining : Since last 25 years, the Indian soils is experiencing, on an average, a net negative balance @ 8-10 mt of nutrients per annum. About 70 per cent of the total gross cropped area in the country experienced a nutrient depletion of more than 50 kg/ha annually. Almost 50 per cent of the nutrient removal is accounted for by potash, whereas its use hardly exceeded 6 per cent. Apparently, potassium accounts for much of this mining or depletion of soil fertility. This is partly because on an average, crops remove 1.5 times more K than they remove N and partly because K application through fertilizer is much lower than that of N or P.

Low Factor Productivity : After enjoying the fruits of green revolution, a decline in the rate of growth of foodgrain production has been observed during recent past in respect of productivity and input response or factor productivity. It is well documented that fertilizer N use efficiency seldom exceeds 40 per cent under lowland and 60 per cent under upland conditions. In case of P and micronutrients fertilizers, the efficiency hardly exceeds 20 and 2 per cent respectively even in the best-managed package of practices.

OPPORTUNITIES

Scope for Increasing Crop Productivity: Although gains in food grain production have kept pace with the population growth, there is a little room for complacency because:

- The productivity performance picture is not at all that encouraging when compared with the China and world average yield levels.
- Any depression in foodgrain production by an abnormal monsoon is likely to produce disastrous effects.
- The need for food will continue to rise in the absence of any reduction in population growth.
- Projected food grain productivity targets cannot be met based on current growth rates.

- The staple rice-wheat and coarse cereal cropping systems are showing signs of fatigue in large areas of the country.

Production targets can be met by increasing yields to levels 2 to 2.5 times higher than current yields. Land is limited and shrinking whereas the human and animal populations are increasing. The land to man ratio has fallen rapidly in the past half century from 0.34 in 1950 to 0.14, and is projected to be 0.10 in 2025. It is also disheartening that India witnessed depressed rates of growth in yield and production compared to world averages.

Increasing Nutrient Demands: Both food and therefore fertilizer needs of India are expected to go up consistently in the future without a break. The net cropped area is continuously decreasing. The population of 1.40 billion plus is expected to grow by 14-15 million each year. At present, each hectare of net sown area has to support more than 7 persons. This pressure will only increase in the coming years. Keeping in view the current conservative population of 1.4 billion and minimum calories requirement of food, the country needs to produce at least 350 mt of food grain and for this purpose it will be necessary to use 35 mt of NPK but in balanced quantities from various sources. In addition, the experts on horticulture, vegetable, plantation crops, sugarcane, cotton, oilseeds and potato have projected that the demand for fertilizers for these high value crops, which also have high export potential and claim fertilizer use on priority basis, will rise to by another 14-15 Mt NPK. Thus, from both inorganic and organic sources the country at present is required to arrange for the supply of about 45 mt of nutrients. Apparently, sustainability of Indian agriculture to maintain food self-sufficiency will depend on the 'high input-high output' principle. The 'low input-high output' concept is merely a dream, and adherence to this invalid view would prove fatal for food security and nutritional security. In the Indian context, this is more true now than ever before because of emerging demands for horticultural, floricultural, and plantation crop products.

STRATIGIES

Narrowing the Productivity Gap

Role of Improved Nutrient Management: There is no doubt that even with the present day's available technology, we are capable of producing many times more food than they are doing today, but there is a big gap between the potential yields and the farmer's yields, between the national demonstration yields and the farmers' yields in India. The current yield levels of the major crops in India is less than the neighbouring countries.

There is wide gap in potential yield and that recorded in on-station and on-farm trials in India. As is evident, the potential yields of crops have not yet been realized in India and emphasis is being laid on increasing food grain production by adoption of improved farm technologies and optimum utilization of production inputs. To sustain the momentum of this objective, a long-term research programme based on higher yields must be instituted to provide the technology for continued higher yields. For developing countries like India, the philosophy of minimum inputs used (particularly fertilizers) can only lead to disastrous results by eventual degradation of the soil, lowering production of crops, destabilization of food supply and finally leading to even more subsistence farming. Maximization of crop yields to achieve increasing food grain production targets would, therefore, be important for India.

In quest to achieve yield goals an integrated multidisciplinary systems approach should be developed. The Maximum Yield Research (MYR) seeks to identify and develop a production system that includes the best of all controllable factors needed to produce the highest possible yield. The MYR on rice-wheat cropping system conducted in India through PPIC support has shown that the production target of 10 t of rice and 6-8 t of wheat can be successfully achieved by adoption of improved varieties, closer crop geometries to sustain higher population stands, and appropriate fertilizer doses. Continuing its efforts in the area of research and education, the PPIC–India Programme has carried out a number of projects with major thrust on: (1) To create greater awareness for high productivity farming and the fact that it can be sustainable as well (2) To convince and persuade various states to take a fresh look at their general fertilizer recommendations and revise them towards more optimal and more balanced levels, as has been achieved on large scale in Uttar Pradesh. Recent research findings of the PPIC-India Programme have established that India's low crop yields can be enormously increased by balanced and efficient use of fertilizers. The maximum economic yields (MEY) of some important crops have been recorded with increased input of fertilizer nutrients, particularly P and K along with secondary and micronutrients and best management practices.

The results of field experiments conducted at PDCSR under AICRPCS in collaboration with PPIC, India Programme have shown the advantages of SSNM as to attain high productivity goals i.e., 11-17 t ha^{-1} of rice and wheat and restoring the soil fertility through restricting the depletion of native nutrient reserves. there is a need to ensure the availability of all required nutrient in time, so as to achieve this target yield level. The system's yields with SSNM treatment ranged from 11 to 16.9 t ha^{-1}, which was almost double to state average, which ranged from 3.0 to 8.1 t ha^{-1}. In this way, the present food grain production could be achieved from half of the presently irrigated area and the rest half area could be utilized for diversification through legumes, pulses, vegetables and other high value crop.

Fertilizer Recommendations: Need a Fresh Look: The available research information sounds well that the existing fertilizer recommendations for NPK are proving to be suboptimal for maximum economic yield. It is also evident that application of nutrients according to current recommendations is causing nutrient depletion particularly in respect of potassium. There is urgent need for upward revision of fertilizer recommendations as the progressive farmers if adopt the adhoc recommendations for crop fertilization purposes the harvested yield many a times remain lesser than their practice.

A linear response to increasing levels of NPK as revealed by rice and wheat yield trends observed in the majority of the 12 long term experiments (LTE) during the initial and final 3 yr of the experimentation (the averages of the initial and final 3 yr were used for regression analysis) clearly indicate that both rice and wheat yields could still be increased with the support of nutrient inputs at higher rates. On the basis of data sets of different LTE, also arrived at similar conclusion suggesting greater inputs of N, P, and K to reach maximum yield targets. Evidently, the normally recommended rates of NPK fertilizers are sub-optimal in multiple cropping system.

The data of the MYR initiated by the PPIC – India Programme revealed that it is possible to surpass the national demonstration yield level by a considerable margin both in rice-rice system in Tamil Nadu and rice-wheat system in the Punjab and Uttar Pradesh by increased NPK application and adoption of improved production technology. This can mean that excessive depletion of soil fertility would demand nutrient replenishment at higher rate.

The comparatively large amounts of P and K relative to N are essential because the plant availability of these nutrients in the soil was so low. Today in India, the P and K levels in many soils are as low or lower than the desired quantities, yet the quantities of P and K used are smaller and N: P_2O_5: K_2O is frequently more unbalanced than that for cereals. An example of how N inputs are used to control productivity and how the efficiency of N use depends on the P and K status of the soil is discussed here.

At low level of available P and K no more than 60 kg N/ ha may be justified for wheat. With adequate K but less than optimum P, only 100 kg N/ha may be justified but with adequate levels of both P and K, 150 kg N /ha would be justified to give maximum yield. This aspect of the role of N in controlling crop productivity, and that of P and K in maintaining soil fertility leads to considerable concern about the wisdom of the current fashion for summing different nutrient inputs.

There is a considerable risk that this could become a hindrance to establishing the correct attitude to soil fertility among both the policy makers and the farmers. Summing nutrient inputs appears to foster a 'league table' approach to fertilizer use, whether it is at the country, district or farm level. For example, "A" using 150 kg/ ha nutrients is perceived to be better than "B" using only 100 kg / ha. But if the 150 kg/ha used by "A" is only N this is much more damaging to long term soil fertility and agricultural sustainability than the 100 kg/ha used by "B" if this consists of 50 kg N, 25 kg P and 25 kg K/ha. If the use of N is separated from that of P and K then different criteria can be applied to their efficient use.

Long term fertilizer experiments of India have started showing similar changing trend to nutrient responses justifying the need for higher rates of P and K application for high yield, high nutrient use efficiency and over all sustainability of agriculture. Unfortunately, it has often been considered that Indian soils with large quantities of micaceous clays will release sufficient potassium to meet crop requirements. This statement may be justified only if the amount of K weathered each year is sufficient to meet all or a significant part of a crop's K requirement. But eventually the amount of K released each year will be too little to meet a crop's requirement and, as such, potash application would be essential and inevitable for sustainable agriculture.

The vast drylands will need increasing attention in which the major focus should be the more neglected foodgrains including pulses and the oilseeds. Sincere efforts to educate farmers about improved farming are needed.

Miseries of Fertilizer Recommendations : The current fertilizer recommendations may either be ad hoc or based on soil tests are not proving to be so effective as to be to achieve desired yield goals. In addition to this, below mentioned are several related problems :

- The current soil-test based recommendations consider only the nutrient deficiency magnitude, not the yield targets. Only one recommendation being currently given without considering the yield target is proving to be sub-optimal for higher yield tar-gets, thus farmers are losing yield, produce quality and profits. The current fertilizer recommendations support only medium yield targets provided the supply of nutrients other than NPK is not a limiting factor. In contrast, the deficiency of one or the other secondary and/or micronutrients is observed in all parts of the country.
- As on date, soil testing laboratories in India do not make recommendations for secondary and micronutrients, because they do not analyse general soil samples for these nutrients. The deficiencies of secondary and micronutrient in majority of the cases are constraining crop

performance resulting in low yield, poor crop quality, low NUE of the applied fertilizers and also posing threat to environment. All the nutrients, which soil cannot supply for optimum yield need to be applied. The PPIC-India Programme's current research thrust has generated good deal of information on this aspects.

- After awareness about correct balanced fertilization, the availability of materials to supply all the needed nutrients would be a great challenge for industry and the policy makers. But ensured supply of the nutrients other than NPK would be essential for sustainable high yield agriculture.

Nutrient Balance Beyond NPK: A Need Indeed: Nutrient balance discussions are often confined to nitrogen (N), phosphorus (P) and potassium (K) because of their major importance in crop production. Also, they are most often the limiting factors that need to be addressed in solving nutrient deficiencies. As nutrient demand goes beyond NPK so the nutrient balance also needs attention beyond NPK, so the increasing productivity targets cannot be achieved without adequate availability of commercial fertilizer nutrients and efficient use of all available resources of organics. Nutrients which must be included in a balanced fertilization programme depend not only on the soil and crop characteristics but also on the yield goal. Findings with tea reveal how the range of nutrients to be applied increase as the yield goal moves from less than 1 t/ha made tea to over 4.5 t/ha as shown below:

Productivity (made tea), kg/ha	**Limiting factor**
Below 800	Nil
800-1000	N and K
1000-2000	N, P, K, Zn + liming
2000-3000	N, P, K, Zn + liming with material containing $MgCO_3$
3000-4000	N, P, K, Zn, Mg, Si, B + liming, transport process within the soil
Above-4500	N, P, K, Zn, Mg, Si, Mo, B + liming transport process within the soil

Balanced fertilization includes wide range of nutrient application strategies from N+Zn in newly-reclaimed alkali (sodic) soils to N+P+K+S+Zn in coarse-textured alluvial soils of the wheat belt and further on to the above-cited case of high-yielding tea under south Indian tropical conditions.

Balancing Nutrient Use: The Road Map

While the projection for large increases in fertilizer use offer equally large opportunities, the "hidden" challenge lies in changing the ratio in which nutrients must be used. All the knowledge that science has helped us gather thus far, tells us that the crop output from an unbalanced 45 M t nutrient can be obtained with smaller tonnage but with a better balance among N: P_2O_5: K_2O. Serious initiatives are needed and must be launched to break this psychological barrier of 4:2:1 (as ideal N: P_2O_5: K_2O ratio) in the Indian mindset particularly among government personnel, both at the center and the state levels. This will not be easy because consumption has not even reached 4:2:1 and in all probability, further fertilizer projections are not aiming at narrowing down this ratio.

Promotion of Use of Smart fertilizers like IFFCO Nano Urea Plus and Nano DAP, Water Soluble Fertilizers, Bioenhancers, Biofertilizers, and Secondary and Micronutrients: Integrated use of innovative fertilizers is a prerequisite to increase nutrient use efficiency and factor productivity for which it is needed to create greater awareness among the farmers about benefits of using these inputs in right quantity, at right time and by right method to transform agriculture, in turn ensuring food, nutrition and environment security and better livelihood of farming community and rural population.

Concluding Remarks

In view of shrinking natural resources, increasing population and climate change risks, balanced and efficient use of fertilizers and other nutrient resources assumes greater importance now than ever before. Adoption of integrated nutrient management strategy and best management practices for fertilizer and water and also the management of secondary and micronutrients deficiencies would be essential and inevitable.

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
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Article ID : 04/IX/12/0924

HARNESSING SENSORS AND INTERNET OF THINGS (IOT) TECHNOLOGY FOR SMART FARMING

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Abstract

Sensors and IoT enabled smart farming is revolutionizing the agricultural sector to address environmental issues and the world's expanding food need. This article discusses the urgent need for smart agriculture techniques and the kinds of sensors that are essential to this strategy. Plant sensors evaluate growth, health, and stress; soil sensors track moisture, pH, and nutrient levels; and specialised water quality sensors guarantee the right amount of nutrient and irrigation. These sensors allow for real-time data collecting, analysis, and automation when integrated with microcontrollers and IoT platforms. Growers can remotely monitor and manage their fields, make data-driven choices, and maximize resource use with the help of this smart farming technology, which increases crop yields and lessens environmental impact. The technical components of this integration are highlighted in this article, which also shows how smart farming technologies are opening doors for more profitable, sustainable, and efficient agriculture in the future.

Introduction

India's economy is based primarily on agriculture, which also makes a major contribution to employment and national productivity. Approximately 54.6% of the workforce works in agriculture and related fields, underscoring the sector's vital significance in generating livelihoods. Agriculture is the primary source of food for more than 60% of the population, highlighting the industry's significance to the socioeconomic structure of the nation. India is a huge country with a land area of 328.7 million hectares, of which 139.4 million hectares are under agriculture (Meena *et al.*, 2024). Moreover, 18.8% of India's GDP is derived from agriculture, demonstrating the sector's significant contribution to the country's economic expansion.

To meet the problems brought on by increasing urbanization and space constraints, smart farming is crucial in metropolitan settings. Even though it has been practiced for generations, traditional agriculture frequently faces problems such as excessive water usage, poor resource utilization, and weather dependence. Reduced crop yields, degraded soil, and more susceptibility to climate change are possible outcomes of these negatives. Smart farming technologies, on the other hand, like hydroponics, vertical farming, and IoT-enabled systems, maximize the use of available resources, minimize the use of water and nutrients, and provide regulated settings that improve crop yields. Cities can overcome the drawbacks of traditional agriculture, improve food security, maintain sustainability, and help create a more self-sufficient and environmentally friendly future by incorporating smart farming into their urban environments.

Traditional farming methods have evolved into what is now referred to as smart farming over time as a result of technological breakthroughs. Modern agricultural operations are incorporating drones, automation, sensors, and the Internet of Things (IoT) as part of this transformation. Farmers have historically been involved in every facet of farming, including planting, fertilizer application, harvesting, and seeding. But with the development of smart agriculture, advanced technology are now handling a large number of these responsibilities. Drones help with precision agriculture by automating activities and offering aerial insights, sensors keep an eye on crop health, and IoT devices provide real-time data collecting and analysis. These innovations not only ease the workload of farmers but also improve efficiency, reduce resource wastage, and enhance overall crop productivity. Smart agriculture thus represents a significant leap forward in the pursuit of sustainable and efficient farming practices.

Smart farming offers numerous benefits, including improved products due to enhanced precision and monitoring. It enables the creation of precise databases, allowing for better decision-making and resource management. The technologies used are environmentally friendly, reducing the ecological impact of farming practices. Efficient management of resources like water, nutrients, and energy is another key advantage. Smart farming also saves time by automating labour-intensive tasks, and with remote applications, farmers can manage their operations from afar. Overall, these advancements provide significant ease to farmers, making agricultural processes more streamlined and sustainable.

Sensors used in smart farming

A sensor is a device that measures a physical quantity such as temperature, humidity, soil moisture, or light and converts it into a signal that can be interpreted by an observer or an instrument. By identifying changes in electrical, physical, or other characteristics within the farming environment, sensors serve a critical role in agriculture. These sensors give off real-time data that can be used to compare current conditions or pre-set values in order to make well-informed decisions. For instance, soil moisture sensors provide ideal irrigation by precisely calculating the water required by crops. Sensors improve agricultural techniques' efficacy and efficiency by offering accurate and useful insights, which help with resource conservation and improved crop management. The different sensors such as soil moisture sensors, nutrient sensors, electrical conductivity sensors, pH sensors, crop disease detection sensors etc. and their integration with IoT are proving beneficial in smart agriculture systems such as protected cultivation, soilless farming, hydroponics, and vertical farming systems.

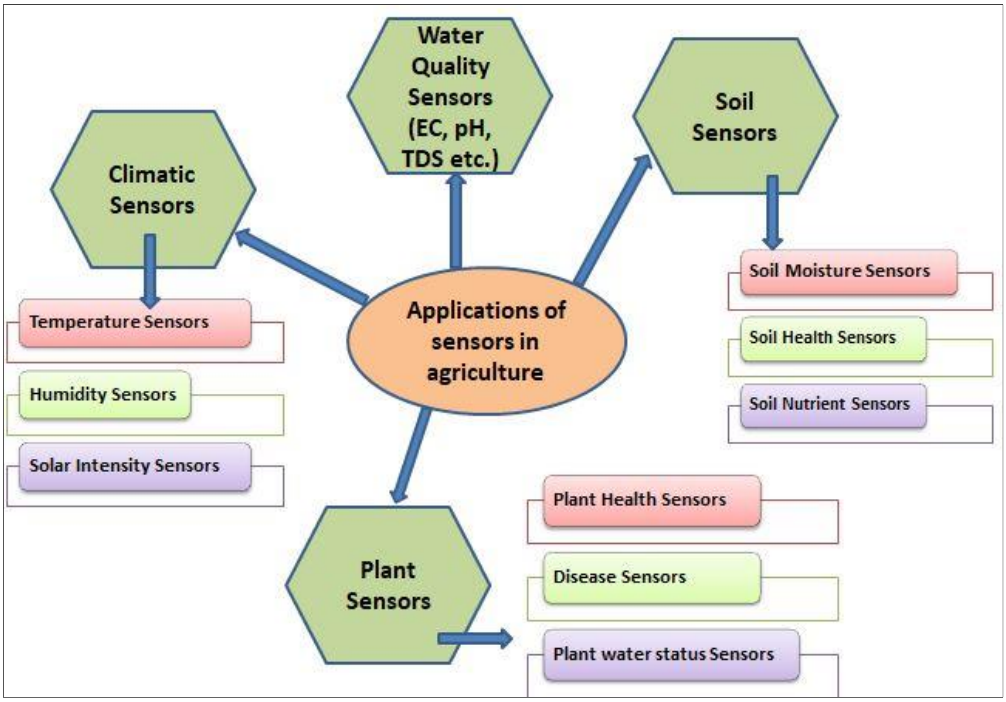

Fig. 1 Flowchart for applications of sensors in smart agriculture

Soil sensors

By delivering real-time data on soil conditions, soil sensors including soil moisture, soil health, and soil nutrient sensors play a critical role in modern agriculture. By measuring the amount of water in the soil, soil moisture sensors assist farmers in making the most of their irrigation techniques. In order to evaluate the general quality of soil, soil health sensors keep an eye on variables including pH, temperature, and microbial activity. With the use of precision fertilization, soil nutrient sensors can measure levels of important nutrients such as potassium, phosphorus, and nitrogen, improving crop yields while having a smaller negative impact on the environment.

An indispensable instrument for determining soil moisture tension and, consequently, the moisture content of the soil is a tensiometer. Farmers may efficiently schedule irrigation, ensuring that crops receive the proper amount of water at the right time, maximizing water usage and crop health, by analysing the soil moisture data gathered via tensiometers. In order to monitor soil moisture levels at various depths and provide accurate measurements that can be connected with controllers and IoT platforms for effective irrigation management, soil moisture sensors are essential. Capacitive and resistive are the two primary types of these sensors. Capacitive sensors use variations in the dielectric permittivity of the soil to determine the moisture content. They are appropriate for long-term usage since they are often more stable and less prone to corrosion. On the other hand, resistive soil moisture sensors gauge the resistance between two soil-inserted probes. Moisture detection is made possible by the resistance's variation with soil moisture levels. Resistive sensors are less expensive, but they are susceptible to corrosion and are impacted by the salt of the soil.

Water quality sensors

Water quality monitoring is essential in smart farming to guarantee ideal irrigation and hydroponic cultivation conditions. Accurate sensors are used to measure important water quality parameters as pH, TDS, and EC. The electrical conductivity of water is measured using EC sensors, and it is directly correlated with the amount of dissolved salts or nutrients present. This aids farmers in keeping crop-use water nutrient-level-appropriate. pH sensors track the water's acidity or alkalinity. For nutrients to be available to plants and for their general health, the pH level must be maintained. Too high or too low of a pH might make it difficult for plants to properly absorb nutrients. Total dissolved solids (TDS) sensors assess the organic matter and inorganic salts that are present in the water. With the help of these sensors, farmers can precisely monitor and regulate the quality of the water, resulting in improved crop yields and ideal growing conditions in smart farming systems.

Plant Sensors

To stop crop diseases from spreading, disease monitoring and control are essential components of smart farming. The sensors that detect crop diseases are essential since they offer up-to-date details on the kind, origin, and degree of disease transmission. Early detection enables farmers to respond promptly, mitigating the effects of illnesses and improving crop health and yield. Furthermore, a variety of characteristics, including temperature, nutrient levels, and the presence of pests or illnesses, are detected by plant health sensors. These variables are measured in order to offer vital information that farmers need to make educated decisions regarding fertilization, irrigation, and pest control. The sensors often use technologies like hyperspectral imaging and chlorophyll fluorescence to assess plant health. When integrated with IoT systems, they enable automated alerts and data-driven management practices promoting sustainable farming practices.

Sensor-Controller-IoT Integration for Smart Farming

Sensor, microcontroller, and Internet of Things integration makes accurate and automated agriculture management possible in smart farming. Sensors gather information on a range of characteristics, including crop health, temperature, humidity, and soil moisture. Microcontrollers, the essential component for decision-making based on predetermined conditions, process this data. Growers can monitor and manage agricultural operations remotely by transmitting the processed data to mobile devices or cloud systems via IoT platforms. For better agricultural results, this integration increases productivity; decreases manual labour, and permits data-driven decision-making (Hasan *et al.*, 2023).

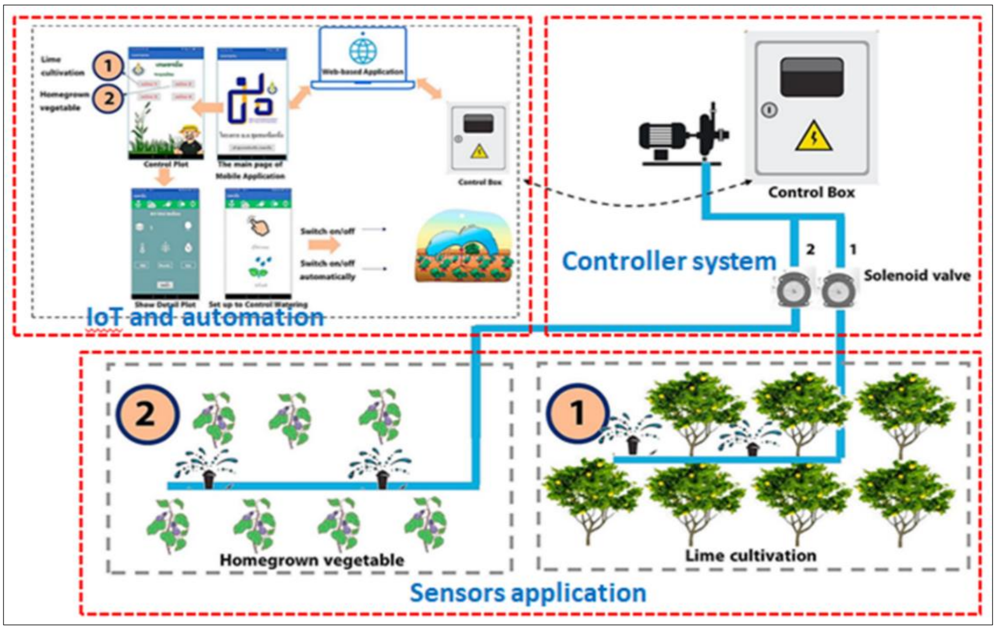

Fig. 2 Representative diagram of Sensor-Controller-IoT Integration for Smart Farming

Use of drones in smart farming

In smart farming, can ensure even coverage and cut down on the amount of chemicals required by spraying fertilizer and insecticides. By delivering real-time airborne data to detect and track the spread of crop diseases, drones also help with disease inspection. Drones are also utilized for mapping cropped areas, which helps farmers make better plans and analyse field conditions. This technology facilitates sustainable farming techniques, lowers labour requirements, and streamlines farm management.

Conclusion

The application of sensors and Internet of Things (IoT) technologies in agriculture marks a substantial advancement toward data-driven, more productive farming methods. Farmers can use precision farming to maximize resource utilization, increase crop yields, and lessen their impact on the environment by utilizing sensors that measure soil, plant, and water quality. This article examines the need for and technological foundation of smart farming, highlighting the ways that sensor-IoT integration is transforming conventional agriculture. In addition to enhancing present farming methods, this technology guarantees sustainability in the face of escalating global issues like food security and climate change. In the future, smart farming will find many uses, from completely automated farms to the creation of AI-powered crop management prediction models. Looking the current scenario, it can be said that, smart farming will develop further as technology progresses, providing creative solutions that raise agricultural productivity and sustainability even higher on a global level.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/13/0924

HORSE GRAM: THE NUTRITIONAL POWERHOUSE

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Introduction

Horsegram (*Macrotyloma uniflorum* (Lam.) *Verdcourt* is a pulse and fodder crop native to Southeast Asia and tropical Africa, but the centre of origin of cultivated species is considered to be southern India (Vavilov, 1951; Zohary, 1970). The name *Macrotyloma* is derived from the Greek words “makros” meaning large, “tylos” meaning knob and loma meaning margin, in reference to knobby statures on the pods (Blumenthal & Staples, 1993). It is a true diploid having chromosome number 2n=2x=20. It is cultivated in India, Myanmar, Nepal, Malaysia, Mauritius and Sri Lanka for food purposes and in Australia and Africa primarily for fodder purposes (Asha *et al*., 2006).

For millennia, the scientific name for horse gram, *Macrotyloma uniflorum*, has been an essential part of Southeast Asian and Indian traditional diets. Horse gram is a nutritional powerhouse that is gradually becoming more widely known in the medical field, despite its humble origins. This paper explores the nutritional qualities of horse gram, highlighting the plant's potential as a health-promoting food by using knowledge from multiple agronomy sources.

Crop status of India : Horse gram is mainly cultivated in the states of Karnataka, Andhra Pradesh, Orissa, Tamil Nadu, M.P., Chhattisgarh, Bihar, W.B., Jharkhand, and in foot hills of Uttaranchal and H.P., in India. It is also cultivated in other countries mainly Sri Lanka, Malaysia, West Indies etc. During Twelfth Plan (2012-2015) in India, the total area under Horsegram and its production during this plan was 2.32 lakh hectares and 1.05 lakh tonnes respectively.In terms of area and production, Karnataka is on the first position on all India basis contributing 26.72% and 25.71% respectively followed by Odisha (19.46%& 15.48%)and Chhatisgarh (19.29% & 13.29%).The highest yield was recorded in the state of Bihar (959 kg/ha) followed by W.B. (796 kg/ha) and Jharkhand (603 kg/ha) (DES, 2015-16).
Source: https://dpd.gov.in/Horse_gram

Varieties:

1. **Rajasthan** KS-2, Pratap Kulthi (AK-42) A.P. Palem-1, Palem-2, Paiyur-2, PHG-9 T.N. Paiyur-2
2. **Karnataka** PHG-9, GPM-6, CRIDA-1-18 R
3. **Gujarat** Pratab Kulthi-1 (AK-42), GHG-5
4. **Uttarakhand** VL- Gahat-8, VL Gahat-10 C.G. Indira Kulthi-1 , (IKGH01-01)

Figure 1: Kulth seeds and plant

Source: Seednet GOI, Min. of Agri. & FW, & ICAR-IIPR, Kanpur

Botanical details: Horse Gram is a twining annual or perennial forming dense growth 30-60 cm high. Trifoliate leaves are 3-7 cm long and 2-4 cm wide. Leaflets are ovate, rounded at the base, pointed or slightly tapering, terminal leaflet symmetrical, laterals asymmetrical, 3.5-5 cm long, 2-4 cm broad, softly woolly on both surfaces, fimbriolate, paler beneath. Yellow or greenish-yellow flowers with violet blot on the standard are borne singly. Pods are 6-8 cm long and 4-8 mm wide with 6-7 seeds. Var. uniflorum is the cultivated annual form which has wider pods. It is drought resistant but cannot withstand waterlogging. Horse Gram is of Indian origin, it is now cultivated in Asia, Africa, West Indies and southern USA as a pulse crop and for fodder. The whole seeds of horsegram are generally utilized as cattle feed. However, it is consumed as a whole seed, as sprouts, or as whole meal in India.

Nutritional composition: Horse gram boasts a remarkable nutritional profile that makes it an excellent addition to any diet. Here's a detailed look at its macronutrient and micronutrient content:

Macronutrients

1. **Protein:** Horse gram is rich in protein, containing approximately 22-24 grams per 100 grams. According to the book "Principles of Agronomy" by S.R. Reddy, this high protein content makes horse gram a valuable source of plant-based protein, especially for vegetarians and vegans.
2. **Carbohydrates:** With around 57-60 grams of carbohydrates per 100 grams, horse gram provides a steady energy supply. "Pulse Crops" by A.E. Hall emphasizes the importance of horse gram in providing a sustained release of energy, beneficial for those with active lifestyles.
3. **Fiber:** Horse gram is an excellent source of dietary fiber, offering about 5-7 grams per 100 grams. The fiber content is highlighted in "Textbook of Field Crops Production" by Rajendra Prasad, which notes its role in promoting digestive health.
4. **Fat:** Low in fat, horse gram contains only about 0.5-1.5 grams per 100 grams. This low fat content is significant for heart health, as noted in "Food Legumes" by R.K. Salunkhe.

Micronutrients

1. **Vitamins:** Horse gram is a good source of essential vitamins such as Vitamin C, Vitamin A, and several B-complex vitamins including thiamine, riboflavin, and niacin.
2. **Minerals:** It is also rich in minerals like calcium, phosphorus, iron, and magnesium. These nutrients play crucial roles in bone health, preventing anemia, and supporting muscle and nerve function.

Health Benefits: The nutrient-dense profile of horse gram translates to numerous health benefits, as corroborated by agronomy literature:

1. **Weight Management:** The high protein and fiber content in horse gram makes it ideal for weight management. These components aid in keeping satiated for longer periods and prevent overeating.
2. **Diabetes Management:** Horse gram has a low glycemic index, which helps in managing blood sugar levels. This property makes it beneficial for individuals, suffered with diabetes.
3. **Heart health:** The low fat and high fiber content of horse gram contribute to heart health by reducing cholesterol levels and maintaining healthy blood pressure.

4. **Health**: Dietary fiber in horse gram promotes digestive health by enhancing bowel movements and preventing constipation. This crop plays an important role in supporting the growth of beneficial gut bacteria.
5. **Rich in Antioxidants:** Horse gram is loaded with antioxidants such as polyphenols and flavonoids, which help combat oxidative stress and inflammation. These antioxidants play a crucial role in preventing chronic diseases and promoting overall health.

Culinary Uses: Horse gram is highly versatile and can be incorporated into various dishes. It is commonly used in soups, stews, salads, and even as a flour for traditional breads. Soaking and sprouting horse gram can enhance its nutrient availability and digestibility.

Conclusion

Incorporating horse gram into our diet can significantly boost nutritional intake and offer numerous health benefits. Whether you are looking to manage weight, control blood sugar levels, or simply enhance your overall health, horse gram is a powerful addition to your culinary repertoire. Backed by various research and traditional practices, this nutritional powerhouse is ready to take its rightful place in modern diets.

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Article ID : 04/IX/14/0924

IMPORTANCE OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM IN AGRICULTURE

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Abstract
Remote sensing and Geographic Information Systems (GIS) are pivotal in modern agriculture, enhancing efficiency, minimizing resource loss, and fostering sustainability. These technologies, especially when combined with Artificial Intelligence (AI) and Machine Learning (ML), significantly advance agricultural practices by enabling precise pest detection, efficient water management, and climate adaptation. Remote sensing offers valuable insights into crop health, soil conditions, and environmental changes, while GIS provides tools for detailed spatial analysis and decision-making. Together, they support improved crop productivity and sustainable farming practices, addressing the growing demand for food as global populations increase. The article is focused to get the basic idea about the applications and importance of remote sensing and geographic information system in agriculture.

Keywords: Remote sensing, Geographic Information Systems, agriculture, soil, water.

What is Remote Sensing?

Remote sensing is the technology of obtaining information about objects or areas from a distance, without having direct or physical contact with the subject. This technology is often used to monitor the Earth's surface through artificial satellites and drones. The data captured by cameras on these satellites can be utilized for a variety of applications. In remote sensing, the Earth's characteristics are evaluated using the electromagnetic spectrum, including visible, infrared, and microwave wavelengths. These wavelength regions have different response characteristics, which help distinguish features like vegetation, bare soil, water, and other similar attributes. Generally, there are two types of remote sensing: passive and active. Passive remote sensing involves using natural light, such as sunlight, while active remote sensing systems use sensors that emit their own energy, interact with the target, and return to the sensor. The images taken are transmitted to ground stations via satellites. To capture these images, sensors like panchromatic cameras are used, which can provide information in various colour bands. This technology can be utilized in several ways in agriculture, such as measuring the area under cultivation with specific crops using remote sensing systems.

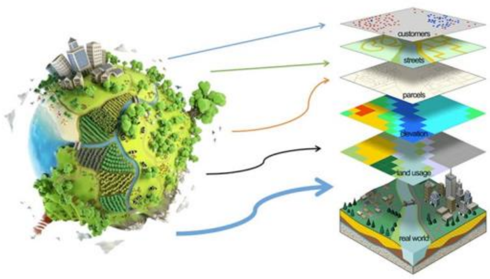
Role of Remote Sensing in Agriculture

Agriculture plays a significant role in the economic systems of all nations. A report by the Food and Agriculture Organization (FAO) states that by 2050, the global population is expected to reach 9.15 billion, necessitating a 60% increase in food production compared to current levels. In India, about 70% of the population relies on agriculture for their livelihood, and the agricultural sector contributes approximately 35% to the gross national product. Given the limited opportunities to expand the cultivated area, increasing agricultural productivity is a matter of concern. For this, proper and optimal management of land and water resources is necessary.

For higher productivity, it is essential to monitor crops in real-time, considering adverse environmental conditions. Remote sensing can be used to study factors such as the current condition of crops, soil components, water availability, and quality, as well as climate change. In recent years, remote sensing has been used extensively to measure the area under cultivation of specific crops, assess crop conditions, manage crop diseases and pests, measure soil moisture and nutrient content, estimate per-acre yield, study climate change, soil surveys, assess flood conditions, manage agricultural water, and study agro-climatology.

What is Geographic Information System (GIS)?

A Geographic Information System (GIS) is a computer system that collects, stores, and uses geographical information to analyse and display data related to a specific area. It allows users to create maps from the collected data and use these maps for analysis. GIS can be used in agriculture in various ways, such as determining the suitability of land for specific crops based on factors like soil structure, soil type, rainfall, and atmospheric conditions. Information and images obtained through remote sensing can be integrated into GIS, allowing users to visualize the data on geographic maps.



Integration of Remote Sensing and GIS

Remote sensing technology is incomplete without the integration of GIS. Remote sensing captures spatial data, while GIS is used to extract information from that data. In recent years, the demand for data obtained through remote sensing systems has increased significantly. To view and process the data, and extract more information and conclusions, GIS is essential.

Applications of RS and GIS in Agriculture

1. Estimating Crop Yield:

Predicting crop yield is essential, though challenging, for planning in the agricultural sector and meeting the growing demand for food. National and international agencies must make decisions regarding crop prices, imports, and exports. In 1980, the Indian Space Research Organisation (ISRO) initiated a project to estimate crop yields and the area under cultivation, which later evolved into the national-level project known as FASAL (Forecasting Agriculture output using Space, Agro-meteorology, and Land-based observations). This project estimates pre-harvest crop yields at the state, district, and taluka levels.

Estimating crop yield using remote sensing is crucial. The system allows for the regular collection of information on the growth stages of different crops in various areas. This information can be used to estimate pre-harvest crop yields. By using vegetation indices, the system provides data on the biomass of the area, and by monitoring the crop growth stages using remote sensing, pre-harvest yield estimates can be made, along with the measurement of the area under cultivation.

2. Identifying Pest and Disease Outbreaks:

Remote sensing systems can be used to identify outbreaks of pests and diseases. Stress on crops caused by insects and diseases leads to external morphological and internal physiological changes in the plants. External symptoms include chlorosis, necrosis, wilting, decay, stunting, and others. Internal physiological changes primarily involve the destruction of chlorophyll tissue, reduced absorption, transportation, and conversion of water and nutrients, leading to decreased respiration and photosynthesis. These symptoms are clearly visible in the vegetation indices of crops. Thus, changes in biomass and crop components due to pest and disease outbreaks can be identified.

3. Water Management and Quality Assessment:

The spectral signature of water varies depending on its composition and impurities, and these variations can be detected through remote sensing. Water acts as a partial diffuse and partial specular reflector, and its spectral response pattern is affected by several factors such as season, sun angle, atmospheric conditions, surface roughness, and the presence of coloured dissolved substances and suspended sediments. By analysing the spectral response of water through satellite imagery, it is possible to assess water quality. Relationships between water quality parameters and spectral responses need to be established to monitor water quality effectively. Such studies help in water management and quality assessment.

4. Testing Soil Fertility

India's soil resources, though rich and diverse, also show deficiencies in nitrogen, phosphorus, and potassium. These are the essential nutrients that enhance food productivity in most parts of the country. Moreover, the availability of nutrients and micronutrients has become limited in many regions. Current knowledge about soil in agriculture, along with local and regional soil maps and assessments of soil fertility, provides substantial information. Soil reflectance information can be obtained in laboratories or fields using instruments like spectroradiometers. These devices can understand the relationship between soil's physical and chemical properties and its reflectance characteristics. Soil composition, texture, moisture, and the presence of iron oxides are factors that have the most significant impact on soil reflectance. To identify areas affected by salinity or saline soils, spectral changes in the vegetation growing in those affected regions can be recognized.

5. Weather Forecasting:

Weather forecasting uses scientific principles to predict future atmospheric conditions, gathering data on humidity, wind, and temperature. Remote sensing plays a crucial role, using satellites and sensors to monitor clouds, radiation, and other atmospheric phenomena. Images captured by sensors help identify cloud cover, snow, and areas not covered by clouds, providing insights into temperature variations and cloud density. High humidity appears as bright shades in sensor readings, and weather radars measure rainfall intensity and wind patterns. These radars offer higher frequency imaging than meteorological satellites, allowing effective monitoring of weather changes, especially in rain-prone areas. Remote sensors in satellites like QuickScat can detect cyclones by measuring scattered microwave signals from ocean waves.

6. Soil Mapping

Soil observation and mapping are crucial for maintaining soil health and improving agricultural productivity. Soil fertility and health are key factors in agriculture, and local information about soil quality is essential for effective land management. Remote sensing and GIS technologies, particularly high-resolution satellite data, play a significant role in soil monitoring. Remote sensing allows farmers to determine soil suitability for different crops and identify areas needing irrigation. It provides detailed information on soil properties like texture, composition, colour, density, slope, and erosion. Maps and data generated from soil observation can be used for land capability classification, which categorizes land into eight classes (I to VIII) based on its suitability for agriculture, with classes I to IV being suitable for farming and classes V to VIII for wildlife sanctuaries and other uses. Similarly, land Irritability classification assesses land based on its irrigation suitability, with classes 1 to 4 being suitable for irrigation and classes 5 to 8 less suitable, with class 6 being entirely unsuitable for irrigation. Remote sensing simplifies the monitoring and measurement of soil and land, aiding farmers, and land users in making informed decisions.

ISSN : 2583-0910
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Article ID : 04/IX/15/0924

UNLOCKING INDIGENOUS PLANT WEALTH: ENHANCING FOOD, NUTRITION, AND HEALTH SECURITY IN BARAMULLA, KASHMIR

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Abstract

The Kashmir Valley, known worldwide for its breathtaking beauty, is also a hotspot of rich biodiversity, especially in terms of medicinal plants. Located at the intersection of the Holarctic and Paleotropical Floristic Realms in the Northwestern Himalayas, Kashmir's diverse flora plays a vital role in the lives of local communities. However, this botanical wealth is under threat due to rapid land use changes, the spread of invasive species, and environmental degradation, leading to the decline of many traditional edible and medicinal plants. With over 1,123 medicinal plant species documented in the region, these plants are crucial for traditional healing practices and have significant potential for modern medicine. Conservation efforts are increasingly urgent as these plants face threats from destructive harvesting and habitat loss. Initiatives like the "Forest Food Festival" have begun to highlight the importance of these wild edibles, demonstrating their uses in both culinary and medicinal contexts. This article emphasizes the need to preserve Kashmir's ethno-botanical heritage and the critical importance of sustainable practices to ensure the survival of these invaluable natural resources.

Key words: Biodiversity, Medicinal Plants, Health security, Ethno-botanical Heritage.

Introduction

The Kashmir Valley, often called a "Terrestrial Paradise," is renowned worldwide. A key factor in its global reputation is the rich biodiversity that graces its stunning landscape. Geographically situated at the crossroads of the Holarctic and Paleotropical Floristic Realms, within the North-Western Himalayas, this region is home to a vast diversity of medicinal plants. A famous quote by Sheikh ul Alam (R.A.), a 14th-century Sufi saint of Kashmir, "*Ann poshi teli, Yeli van poshi*" (Food will suffice till forests survive), underscores the ancient understanding of the vital connection between forests and food production. Forests, as repositories of wild relatives of our food crops, also provide habitat for pollinators like bees, butterflies, beetles, and birds, which are essential for agriculture. Additionally, healthy soils contribute to groundwater recharge, and vegetation on mountain slopes helps regulate rainwater runoff, preventing flash floods and droughts, thereby sustaining agriculture.

However, the traditional use of edible herbs by rural and ethnic communities is declining due to rapid land-use changes, the spread of exotic weeds, invasive species in disturbed soils, and the displacement of native edible plants such as Dandelion, Purslane, Senna, Teasel, Nepal Dock, edible Campion, Starwort, Venus comb, Henbit, Adder's tongue, Medick, Paklana vine, and Meadow Buttercup. These forest plants hold significant potential for innovative value addition and should be cultivated outside forests to support both biodiversity conservation and the sustainable use of wild edible products. These herbs are also crucial in the production of Ayurvedic and Unani medicines. To raise awareness about them, the Department of Environment, Ecology, and Remote Sensing of the Jammu and Kashmir government, in collaboration with the Centre for Conservation of Culture & Heritage (CCCH) and the Institute of Hotel Management Srinagar, organized the first-ever "Forest Food Festival" on October 4, 2015, in Srinagar. During the event, the uses of over 100 herbs were demonstrated, and around 35 dishes were prepared using these herbs (Subiya *et al*., 2018).

Diversity, distribution and traditional uses of medicinal plants in Jammu and Kashmir (J&K) of Indian Himalayas

Jammu and Kashmir (J&K), nestled in the Indian Himalayas, is rich in biodiversity, particularly in its variety of medicinal plants. Documenting the diversity, distribution, and traditional uses of these plants is crucial for their conservation and sustainable management in this region. This study, which combines extensive ethno-medicinal surveys conducted over the last decade with a systematic review of existing literature, has created an extensive database of J&K's medicinal plants. The database includes 1,123 plant species known for their medicinal uses in the state, with 78% of these species being native to the Himalayan region. Traditional practices often utilize the entire plant, though leaves and underground parts are also commonly used. These medicinal species are employed to treat 266 different ailments. The study identifies 20 key medicinal plants, each of which is used to treat more than 25 diseases. Among these, *Taraxacum officinale* and *Aconitum heterophyllum* are the most frequently cited species based on their relative frequency citation (RFC) value.

This study, with its rigorous taxonomic approach, offers one of the most comprehensive and up-to-date assessments of the medicinal flora in J&K. The insights gained from this research have significant potential for guiding the discovery, development, and design of future medicinal drugs.

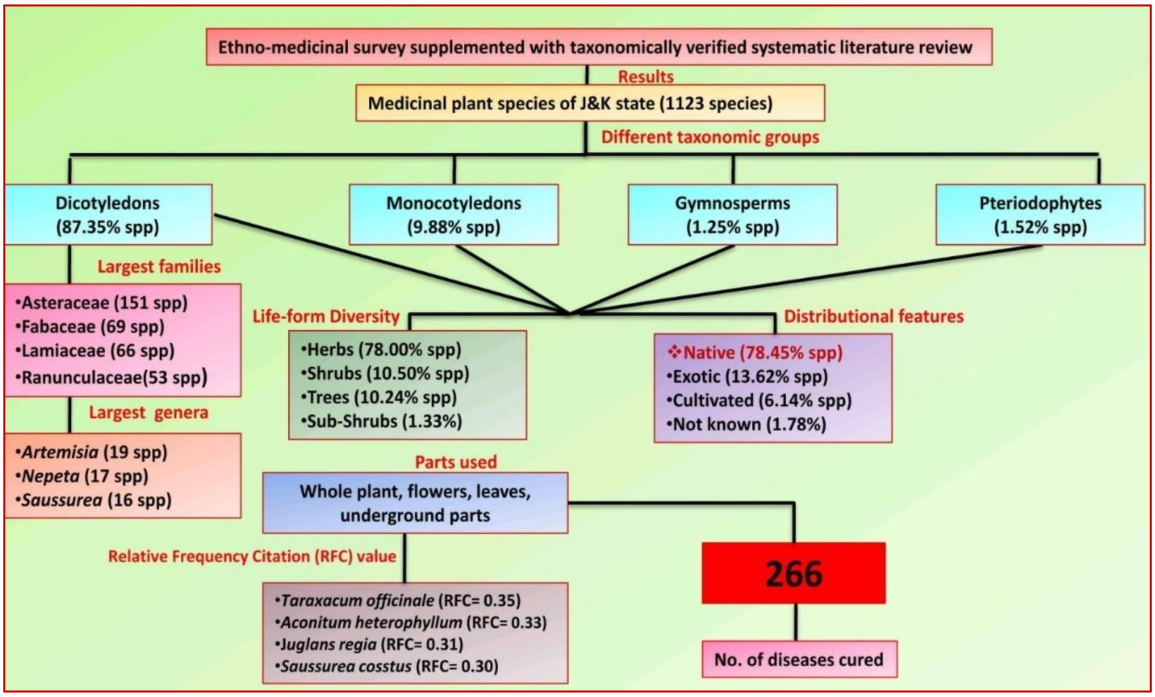

Fig.1. Diversity, distribution and traditional uses of medicinal plants in Jammu and Kashmir (J&K) of Indian Himalayas

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An Ethnobotanical Value of Wild Edible and Medicinal Plants of District Baramulla, Jammu and Kashmir

Wild plants are essential to the livelihoods of rural communities and many developing countries. In numerous developing regions, a significant portion of the population struggles to meet their daily nutritional needs, with many lacking essential micronutrients (FAO, 2004). This is also true in India, the world's second most populous country. In India, rural communities often rely on wild edible plants to sustain themselves during food shortages and as a source of additional nutrients. Arora and Anjula (1996) provided a comprehensive overview of the wild edible plant species found in India. These plants are not only vital for nutrition but also serve as invaluable traditional remedies for various diseases, highlighting their importance as natural sources of medicine.

Study Area

The Union Territory of Jammu & Kashmir, located at the northernmost tip of India, is positioned between latitudes 32°17′ and 36°58′ N and longitudes 37°26′ and 80°30′ E. Baramulla, one of the 22 districts in J&K, sits at an average elevation of 1,581 meters above mean sea level and covers an area of 4,191 square kilometers. The district extends between latitudes 32°58′ and 35°50′ N and longitudes 73°45′ and 75°20′ E. It is bordered to the north by Kupwara district, to the south by Budgam, Poonch, and parts of Srinagar, and to the east by Ladakh, while the Line of Control marks its western boundary. Baramulla experiences a Mediterranean climate with four distinct seasons: spring, summer, autumn, and winter. Temperatures range from a low of -0.03°C in January to a high of 30.1°C in July, with an average annual rainfall of 1,270 mm. The district's forests are a crucial resource, covering 2,963 square kilometers, which is about 71% of the district's total area. Field studies and surveys have been conducted in various areas including Tangmarg, Kreeri, Sopore, Pattan, Gulmarg, and Rafiabad (Jeelani *et al*., 2013).

Plant Wealth

Baramulla district in Jammu & Kashmir showcases a remarkable variety of edible plants. As the largest district in the valley, Baramulla has the highest number of villages where plants are extensively used as vegetables. Research on the diversity of edible species in the region has identified 33 plant species from 17 families that are traditionally utilized by local communities for daily consumption. Among these families, Asteraceae has the highest number of species (four), followed by Amaranthaceae, Apiaceae, Brassicaceae, and Rosaceae, each with three species (figure 1). Additionally, studies indicate that ethno-botanical plants have been a staple in the diet of Baramulla's residents from historical times (Table 1) (Muzafar *et al*., 2015).

Ethno-botany of Some Threatened Plants in District Baramulla,Kashmir, Jammu and Kashmir, India

During various ethno-botanical surveys, 27 threatened plant species were recorded along with their traditional uses. Among these, 8 are classified as rare, 7 as vulnerable, 7 as endangered, and 5 as critically endangered. These species belong to 22 different plant families, with most being herbs. They have been used since ancient times to treat various ailments such as coughs, fevers, rheumatism, constipation, and boils (Farooq *et al*., 2014).

The Kashmir Himalaya is known for its rich diversity of medicinal plants. However, approximately 70% of these plants are subject to destructive harvesting practices (Khan *et al*., 2004). In Jammu & Kashmir, India, the collection of medicinal plants from the wild is generally banned, with exceptions made only for the Gaddi, Gujjars, and Bakarwal tribes, who are allowed to gather plants for personal use. As a result, knowledge about these plants is primarily held by these tribal communities (Dutt *et al*., 2015).

Recent concerns about biopiracy and intellectual property rights, given the significant economic stakes, underscore the need for prompt bio-prospecting of medicinal plants used in traditional practices. A crucial first step is documenting the ethnomedicinal uses of these plants. This indigenous knowledge could then be developed into commercial products on an industrial scale, ensuring that the benefits are shared among all stakeholders and protecting our biological resources from exploitation (Zishan *et al*., 2016).

Table 1. List of wild edible plants used by local people of (Tangmarg, Kreeri, Sopore and Pattan) Baramulla, Jammu & Kashmir.

S. No.	Botanical name/ Family	Vernacular name	Part used	Uses
1	*Amaranthus caudatus* L. Amaranthaceae	Leesa	Whole plant	Herb is used as Vegetable
2	*Capsella bursa pastoris* L. Brassicaceae	Kralmund	Whole plant	Used as vegetable
3	*Malva neglecta* L. Malvaceae	Sochal	Leaves	Used as vegetable
4	*Mentha longifolia* L. Lamiaceae	Pudina	Whole plant	Shoots are used as vegetable. Also used as Condiment.
5	*Morus alba* L. Moraceae	Tul	Fruits	Fruits are eaten.
6	*Plantago lanceolate L.* Plantaginaceae	Gul	Leaves	Fresh leaves are used as vegetables.
7	*Plantago major L.* Plantaginaceae	bud gul	Whole plant	Used as vegetable in Juvenile stage.
8	*Ranunculus arvensis L.* Ranunculaceae	Cherim	Whole plant	The green part of the plant before flowering is cooked and is used as vegetable.
9	*Ranunculus muricatus L.* Ranunculaceae	Thul Hakh	Whole plant	Before flowering the plant is used as vegetable.
10	*Rumex acetosa L.* Polygonaceae	Abjie	Whole plant	Vegetable in juvenile stage.
11	*Taraxacum officinale* F.H.Wigg. Asteraceae	Handh	Leaves	Young leaves are cooked and used as vegetable.
12	*Solanum nigrum* L. Solanaceae	Cambli kul	Fruits	Fruits are eaten.
13	*Cichorium intybus L.* Asteraceae	Posh handh	Whole plant	Used as vegetable especially by women during pregnancy.
14	*Berberis lycium* Royle. Berberidaceae	Kawdach	Leaves	Raw leaves are eaten
15	*Vicia sativa* L.	Hibill hamb	Fruits	Beans are cooked as vegetable

S. No.	Botanical name/ Family	Vernacular name	Part used	Uses
	Fabaceae			and raw beans are also eaten
16	*Scandix pectin veneris* L. Apiaceae	kachkagin	Leaves	leaves are used as vegetable
17	*Sisymbrium loeselli* L. Brassicaceae	Throughe	Leaves	leaves are cooked as vegetable
18	*Torilis scabra* Adans. Apiaceae	Moharmund	Roots	roots are used as vegetable
19	*Lactuca serriola* L. Asteraceae	Dodhkandicj	Leaves	leaves are used as vegetable
20	*Nepeta cataria* L. Lamiaceae	Gand soii	Leaves	leaves are used as vegetable
21	*Urtica dioica* L. Urticaceae	Soii	Leaves	leaves are used as vegetable
22	*Portulaca oleracea* L. Portulaceae	Nunar	Leaves	leaves are used as vegetable
23	*Chenopodium album* L. Amaranthaceae	kunne	Leaves	leaves are cooked as vegetable
24	*Stellaria media.*L Caryophyllaceae	Narumnor	Whole plant	cooked as vegetable
25	*Centaurea iberica* Trevir & Spreng. Asteraceae	Kreaxeh	Leaves	leaves are used as vegetable
26	*Polygonum aviculare* L. Polygonaceae	Drubbe	Leaves	leaves are cooked as vegetable
27	*Nasturtium officinale* W.T.Aiton. Brassicaeae	Nagbabur	Leaves	leaves are used as vegetable
28	*Cuminum cyminum* L. Apiaceae	Zxueer	Fruits	Fruits are eaten.
29	*Rosa indica* L. Rosaceae	Gulab	Flowers	Flowers are used in Kashmiri kehwa and khembeer
30	*Rubus niveus* Thunb. Rosaceae	chhanchh	Fruits	Fruits are eaten.
31	*Amaranthus paniculatus* L. Amaranthaceae	Wazig lissi	Leaves	leaves are cooked as vegetable
32	*Morchella esculenta* Fr. Morchellaceae	Guich	Whole plant	Fruiting body is used as vegetable
33	*Rubus ulmifolius* Schott. Rosaceae	chhanchh	Fruits	fruits are eaten

Source: International Journal of Research & Review (An Ethnobotanical Study of Wild Edible Plants ofDistrict Baramulla Jammu and Kashmir)

Crop based Institutes/Boards in Kashmir responsible for management and utilization of various plants and plant products

- ICAR-NBPGR Regional Station-Srinagar , CITH-Campus, Rangreth, Srinagar
- Sher-e-Kashmir University of Agricultural Sciences and Technology,Kashmir (SKUAST-K), Shalimar, Srinagar
- ICAR-Central Institute of Temperate Horticulture (CITH), Rangreth, Srinagar
- Mountain Research Centre for Field Crops(MRCFC)/ Rice Research and Regional Station, Khudwani (Kulgam), Anantnag
- Saffron Research Station
- Ambri Apple Research Centre, Shopain
- Medicinal plant Board (MPB)-2001
- Department of Health and Medical Education
- J&K Forest Department
- Department of Environment, Ecology and Remote Sensing of Jammu and Kashmir government
- Centre for Conservation of Culture & Heritage (CCCH) and Institute of Hotel Management Srinagar.

Conclusion

Plants have long been crucial as a natural food source, providing nutritious leaves, flavorful fruits, and other parts like bulbs and seeds, especially during times of scarcity. District Baramulla, renowned for its rich variety of medicinal plants, also boasts a deep-rooted tradition of using these plants among its people. The edible plants identified are commonly utilized throughout Baramulla, particularly in areas like Tangmarg, Kreeri, Pattan, Sopore, and Baramulla itself. However, traditional knowledge about these plants is diminishing due to urbanization. Additionally, many plant species face significant threats to their survival. Major threats include overgrazing, deforestation, overexploitation, floods, soil erosion, and the impact of tourism. As a result, numerous plants have become vulnerable, endangered, or critically endangered. Baramulla also serves as a habitat for several rare plant species. Therefore, it is imperative to urgently document this valuable ethnobotanical knowledge and implement effective conservation measures to protect these essential plants.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/16/0924

INTEGRATED PEST MANAGEMENT (IPM) IN ONION (*Allium cepa* L.)

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Abstract

Onion (*Allium cepa* L.) is a vital crop cultivated globally, facing significant challenges from various pests and diseases that threaten yield and quality. Traditional reliance on chemical pesticides has led to environmental pollution, health hazards, and the development of pest resistance. Integrated Pest Management (IPM) offers a sustainable and effective approach to addressing these issues. This article explores IPM in onion cultivation, emphasizing the integration of cultural, biological, mechanical, and chemical control methods. Key components include crop rotation, the use of resistant varieties, biological control agents, and targeted pesticide application. IPM not only reduces pesticide reliance but also promotes environmental sustainability, economic efficiency, and human health.

Keywords: Integrated Pest Management, pest control, biological control, cultural practices, ecological engineering for pest management

Introduction

Onion (*A. cepa* L.) is a vital crop cultivated globally for its culinary and medicinal values. However, onion production faces significant challenges from various pests and diseases, which can drastically reduce yield and quality. Integrated Pest Management (IPM) is a sustainable approach that combines different management strategies and practices to control pest populations effectively.

Identification of pests

1. Onion thrips: *Thrips tabaci* Lindeman (Thysanoptera: Thripidae)

Thrips are minute insects (1.5 mm long), with elongated bodies that are yellow and brown. They possess two pairs of fringed wings and asymmetrical, beak-like mouthparts, along with 7-segmented antennae. Thrips are weak fliers but can easily move from plant to plant or be carried long distances by the wind. Female thrips reproduce parthenogenetically and deposit eggs individually into leaves. The adult lifespan is approximately one month, with a pre-oviposition period of one week, during which females lay eggs for about three weeks.

2. Onion maggot: *Delia antiqua* Meigen (Diptera: Anthomyiidae)

Maggots are small (8 mm), legless, and tapered with a creamy-white colour. They develop through three larval stages over a period of 2 to 4 weeks, depending on the climatic conditions. Newly hatched larvae crawl to the root surface, where they begin feeding using their hooked mouthparts, eventually reaching the basal plate of the bulbs. This feeding activity causes the bulbs to start rotting, and the leaves to wilt, become flaccid, and ultimately die. Feeding by third-generation maggots on late-season onion bulbs results in an unmarketable product

3. Red spider mite: *Tetranychus cinnabarinus* (Boisduval) (Trombidiformes: Tetranychidae)
Adult female mites are small, reddish, and elliptical with black spots on either side of their bodies. They can live up to 24 days and lay around 200 eggs during their lifetime. Both adults and nymphs primarily feed on the undersides of leaves. This feeding activity causes the upper surface of the leaves to become stippled with tiny dots from the feeding punctures. The mites tend to feed in "pockets" particularly near the midrib and veins. Silk webbing produced by these mites is typically visible. Over time, the leaves become bleached, discoloured, and may eventually fall off.

4. Cutworm: *Agrotis ipsilon* (Noctuidae: Lepidoptera)
Adult moths are nocturnal and are attracted to lights. Forewings are dark brown to black with distinctive markings, kidney-shaped spot and a dark, jagged line near the edge. The hindwings are lighter, usually whitish-gray with dark veins. Larvae are nocturnal feeders, during the day time hiding in the soil or under debris. They are called cutworms because they cut seedlings at or near the soil surface while feeding at night.The larva cuts through the stalks and causes wilting and death of crop.

5. Beet armyworms: *Spodptera exigua* (Noctuidae: Lepidoptera)
Beet armyworm moth, forewings are grayish-brown with irregular, mottled patterns, and kidney-shaped mark near the center. The hindwings are white with dark margins. Adults are nocturnal and are attracted to light. They are capable of flying long distances, which aids in their widespread distribution. Early instars larva scrapes the leaf tissues, leaving the epidermal layer intact, while the later instar larva causes extensive defoliation and it appear the white papery patches.

Integrated Pest Management (IPM) in Onion Cultivation
Monitoring: Pest population and natural enemies are monitored timely, which helps to decide the suitable pest management strategy at the right time.

Pheromone traps: Pheromone traps should be installed at 5 per acre for targeting insects such as *A. ipsilon,* and *S. exigua*. Install traps at intervals greater than 23 m (75 feet) around the chosen field area. Fix the traps at one foot above the crop canopy, and lures should be changed at a 2-3-week interval.

Light traps: Light traps are used to monitor the activity of nocturnal insects. Install light traps at 1 trap per acre, fixed at 15 cm above the crop canopy, and operate these traps from dusk at 6:00 PM to 10:00 PM for more effective monitoring than during the day.

Blue sticky traps and yellow sticky traps: For monitoring thrips populations, install blue or yellow sticky traps at 5 traps per acre, positioned 15 cm above the crop canopy. Easy and locally available empty containers or tins can be used as effective traps by painting their outer surfaces blue or yellow and coating them with castor oil or grease. These traps should be replaced every two weeks. Additionally, these traps will also trap midges, flies, and other insect species.

Cultural control

- Avoid successive plantings of onions.
- Practicing crop rotation with non-host plants minimizes the chance of pest carryover.
- Adequate irrigation throughout the growing season is a critical factor in minimizing thrips infestation.
- Colour-sensitive mulches (aluminum-coated) may be effective and reduce thrips population by 30-70%.

- Early planting/transplanting of onions is effective in managing thrips and increasing bulb yields.
- Onion varieties with an open neck and dark, glossy leaves are less attractive to thrips than varieties with tight necks and lighter green leaves.
- Additionally, using sprinkler irrigation to mimic rainfall helps reduce the thrips population.
- Inadequate soil calcium and high nitrate levels invite higher population thrips.
- Avoid close planting to control onion maggots, and flood irrigation reduce mite population.
- Use the resistant variety TNAU hybrid CO2 for managing purple blotch, and TNAU hybrids CO_2, CO_3, and CO_4 for controlling thrips.

Ecological engineering for pest management – Above ground
Raise the flowering plants along the field border by arranging shorter plants towards the main crop and taller plants towards the border to attract natural enemies and prevent pest migration. Not to uproot weed plants that are growing naturally, like *Tridax procumbens*, *Ageratum* sp., and *Alternanthera* sp., as they serve as nectar sources for natural enemies. Erect bird perches (20 per acre) to encourage predatory birds such as mynah and king crows against lepidopteran pests. Barrier cropping: Two rows of maize were planted outside and wheat on the inner side at least two weeks before the sowing of the onion.

Ecological engineering for pest management - Below ground
Crop rotations with leguminous crops enhance nitrogen content and add organic matter, *viz*., farmyard manure (FYM), vermicompost, and crop residue, which enhance below-ground biodiversity. Apply a balanced dose of biofertilizers. Like plant growth promoting rhizobacteria (PGPR) and mycorrhiza. Soil application and seed / seedling dip with *Trichoderma viride* and *Basillus suptilis* reduce plant disease and promote the root growth of onions.

Biological control
Conserve and augment natural enemies like syrphid flies, damselflies, rove beetles, chysoperllas, praying mantises, and spiders.

Thrips: Utilize parasitoid, *Ceranisus menes* (nymph); predators like Syrphid flies, anthocorid bugs (*Blaptosthethus* sp., *Buchananiella whitei, Orius tantilus*); predatory thrips (*Aeolothrips fasciatum*); coccinellids (*Cheilomenes sexmaculata*); spiders, etc.

Onion maggot: Parasitoid**,** braconid wasp (*Aphaereta pallipes*) and predators, rove beetle, ground beetle, spiders, *etc*.

Mite: Predators**,** such as Anthocorid bugs (*Orius* spp.), mirid bugs, predatory mites (*Amblyseius alstoniae*, *A. womersleyi, A. fallacies,* and *Phytoseiulus persimilis*), predatory cecidomyiid fly (*Anthrocnodax occidentalis*), predatory gall midge (*Feltiella minuta*), spiders, etc.

Lepidopteran insect: To release the egg parasitoid, *Trichogramma pretiosum* @ 4,000 per acre 4- 5 times at weekly interval during flowering stage. Additionally, Conserve the natural enemies such as *T. chilonis, Tetrastichus* spp. *Telenomus* spp. (egg), *Chelonus blackburni, Carcelia* spp., *Campoletis chlorideae*, *Bracon* spp., *Chrysoperla zastrowi sillemi*, coccinellids, King crow, common mynah, wasp, dragonfly, spider, robber fly, reduviid bug, praying mantis, pentatomid bug (*Eocanthecona furcellata*), earwigs, ground beetles and rove beetles.

Chemical control

Chemical control is a significant component of IPM in onion cultivation, offering effective means to manage pest populations. However, it is crucial to use chemical pesticides judiciously to minimize environmental impact, human health risks, and development of pest resistance. Insecticides should be applied based on need, using a knapsack sprayer to ensure targeted and efficient application.

Insect	Insecticide	g/ml/acre
Thrips	Deltamethrin 11% w/w EC	60
	Dimethoate 30 % EC	264
	Fipronil 80 % WG	30
	Lambda-cyhalothrin 05 % EC	120
	Oxydemeton-methyl 25 % EC	480
	Tolfenpyrad 15 % EC	400
Mites	Sulphur	100
	Dicofol	400

Challenges and Future Directions

1. **Adoption and Awareness:** Educating farmers about the benefits and practices of Integrated Pest Management (IPM) is essential for its widespread adoption. Extension services and farmer training programs can play a vital role.
2. **Research and Development:** Continuous research on pest biology, development of resistant varieties, and new biocontrol agents is essential. In addition, creating user-friendly pest monitoring tools and decision support systems can enhance the effectiveness and accessibility of IPM practices.
3. **Policy Support:** Government policies and incentives can encourage the adoption of IPM practices. Subsidies for biocontrol agents and IPM tools can make them more accessible to farmers.

Conclusion

Integrated Pest Management is a holistic approach that offers sustainable solutions to pest problems in onion cultivation. By combining cultural, biological, mechanical, and chemical methods, IPM reduces the environmental impact of farming, enhances economic returns, and promotes human health. The successful implementation of IPM requires the collaboration of researchers, extension workers, and farmers. As global demand for onions continues to rise, IPM stands as a cornerstone for sustainable and productive onion farming.

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ISSN : 2583-0910
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Article ID : 04/IX/17/0924

MANAGING PYOMETRA IN DOGS: EARLY DETECTION, TREATMENT AND PREVENTION

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Abstract

Pyometra is a severe, potentially life-threatening uterine infection affecting unspayed female dogs, typically occurring a few weeks after a heat cycle. The condition is caused by hormonal changes that lead to bacterial infection within the uterus, with symptoms varying between open (visible discharge) and closed (no discharge) forms. Early detection is critical, as pyometra can rapidly progress, causing sepsis, organ failure, and death if left untreated. The most effective treatment is surgical removal of the infected uterus and ovaries, though medical management may be considered in specific breeding cases. Preventive measures, including spaying and regular monitoring, are key to avoiding this dangerous condition and ensuring a healthy life for dogs.

Introduction

Pyometra is one of the most serious and potentially life-threatening conditions affecting unspayed female dogs. This condition, a uterine infection, typically develops within a few weeks after estrus due to hormonal imbalances and bacterial invasion. As a common issue in unspayed middle-aged to older dogs, pyometra is something all dog owners should be aware of, given its rapid onset and potentially fatal outcome if left untreated. In this article, we'll explore the importance of early detection, available treatment options, and strategies for prevention to keep your canine companions safe.

Understanding Pyometra in Dogs

Pyometra occurs when the uterus becomes infected, leading to the accumulation of pus within the uterine cavity. After a dog's heat cycle (estrus), the hormone progesterone remains elevated to prepare the uterus for possible pregnancy. If pregnancy does not occur, this prolonged hormonal stimulation can cause the uterine lining to thicken, creating a favorable environment for bacterial growth. The bacteria, most commonly *Escherichia coli* (*E. coli*), often enter through the cervix when it is open during estrus. Once the infection sets in, it leads to inflammation and pus accumulation within the uterus.

This condition typically affects middle-aged or older dogs, though it can occur at any age. The risk increases with each heat cycle, especially in dogs that have never been bred. Some breeds, such as Golden Retrievers, Rottweilers, and Bernese Mountain Dogs, are thought to be more predisposed to pyometra. Understanding the underlying hormonal and bacterial causes is essential for identifying high-risk dogs and implementing timely intervention.

Recognizing the Signs and Symptoms

The symptoms of pyometra can vary depending on whether the dog has an "open" or "closed" pyometra. The cervix remains open in open pyometra, allowing the infected discharge to drain from the body. This discharge is typically foul-smelling, pus-like, and can vary in color from yellow to reddish-brown. Other signs include lethargy, loss of appetite, increased thirst (polydipsia), and excessive urination (polyuria). Dogs may also display a reluctance to exercise, signs of abdominal pain, or general discomfort.

Closed pyometra is even more dangerous because the cervix is sealed, trapping the infection within the uterus. Without a visible discharge, the symptoms are more subtle but escalate quickly. Dogs with closed pyometra may exhibit severe lethargy, a distended abdomen, vomiting, diarrhea, and signs of shock as the infection spreads into the bloodstream. In both types, early detection is crucial as the condition can progress rapidly, leading to sepsis, organ failure, and death if left untreated.

Given the life-threatening nature of pyometra, dog owners should be vigilant, especially if their dog is unspayed and has recently gone through a heat cycle. Recognizing early warning signs and seeking immediate veterinary attention can significantly improve outcomes.

Diagnosis and Treatment Options

Veterinarians diagnose pyometra based on clinical signs, medical history, and diagnostic tests. An abdominal ultrasound is the most reliable diagnostic tool, allowing visualization of the enlarged, pus-filled uterus. In some cases, X-rays may also be used, although ultrasound provides more detail. Blood tests typically reveal elevated white blood cell counts, indicating infection, as well as possible dehydration and kidney dysfunction. In cases of closed pyometra, where symptoms are less obvious, these diagnostic tools are essential for confirming the presence of the infection.

Treatment for pyometra generally depends on the severity of the condition, but in most cases, emergency surgery is required. An ovariohysterectomy (spaying) involves removing the infected uterus and ovaries, effectively eliminating the source of the infection. This is the most common and successful treatment option, especially for dogs that are not intended for breeding. Surgery carries some risks, especially in older dogs or those in critical condition, but it remains the gold standard for treatment.

For owners of younger dogs intended for breeding, medical management may be considered in cases of open pyometra. This typically involves administering prostaglandins to expel the uterine contents and antibiotics to control the infection. However, medical management carries a higher risk of recurrence and is generally less effective than surgery. Moreover, it is not recommended in cases of closed pyometra due to the risk of the uterus rupturing. Given the complexities of treatment, most veterinarians advocate for surgical intervention as the safest and most definitive solution.

Why Early Detection is Critical

The key to managing pyometra successfully lies in early detection and prompt treatment. As the condition can progress rapidly, even a delay of a few days can lead to life-threatening complications.

In cases of closed pyometra, where symptoms are more subtle and there is no visible discharge, the infection can reach a critical stage before it is noticed. Early detection through awareness of symptoms and timely veterinary care can dramatically improve the prognosis.

Dogs with pyometra, especially those with closed pyometra, are at a higher risk of sepsis, where the infection spreads throughout the body, leading to multiple organ failures. Once sepsis sets in, emergency surgery becomes more complicated, and recovery becomes more uncertain. Educating dog owners on the importance of recognizing early signs, such as changes in drinking habits, lethargy, and unusual discharge, is crucial in preventing delays in treatment.

Prevention and Long-Term Management

The most effective way to prevent pyometra is through spaying (ovariohysterectomy), which involves removing both the ovaries and uterus. Spaying not only eliminates the risk of pyometra but also significantly reduces the likelihood of other reproductive diseases, such as mammary tumors. For dog owners who do not plan to breed their pets, spaying is highly recommended before the dog reaches middle age.

For those who choose not to spay, regular veterinary checkups are essential, especially after each heat cycle. Monitoring for any unusual signs, such as abnormal discharge, lethargy, or changes in behavior, can help in detecting the early stages of pyometra. It's also important for owners to be aware that even if pyometra is treated successfully without surgery, the condition is likely to recur. For this reason, spaying is often recommended after the initial treatment.

In summary, pyometra is a common but preventable condition in unspayed female dogs. Early detection through vigilant observation and timely veterinary care is key to avoiding severe complications. With proper awareness and preventive measures like spaying, dog owners can protect their pets from this life-threatening condition, ensuring a healthier and longer life for their canine companions.

Acknowledgment : ChatGPT, an AI-powered chatbot (https://www.openai.com/chatgpt) was used for language modulation.

ISSN : 2583-0910
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Article ID : 04/IX/18/0924

EXPLORING NANOTECHNOLOGY APPLICATIONS FOR ENHANCEMENT PLANT DISEASE MANAGEMENT: A SUSTAINABLE USE

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Abstract

Plant pathogens cause significance reduction in production (20-40%) of various crops. Current disease management relies heavily on the application of chemicals like fungicide, bactericides and nematicides. Before nanotechnology plant disease control faced several challenges and limitations. Some of these includes: Limited Precision, Resistance Development, Environmental Impact, Health Concerns, Limited Efficacy. Nanotechnology offers several benefits and applications in agriculture, making it an increasingly important field of research. Nanotechnology has offered promising solutions to address many of these challenges by providing more targeted and environmentally friendly approaches to plant disease control. Nanotechnology is the manipulation and control of matter at the nanoscale, typically involving structures, devices, or materials with at least one dimension sized from 1 to 100 nanometers. The term "nanotechnology'' was coined by (Taniguchi) in 1974. (Dr. Karnika De Silva et al.) has worked on developing nanotechnology-based solutions for plant disease management, particularly focusing on using nanoparticles for controlling fungal diseases. It shows promise in addressing various plant diseases which includes: Fungal Diseases, Bacterial Diseases, Viral Diseases, Nematode infestations, Abiotic Stress. Studying nanotechnology for plant disease management offers several compelling reasons: Enhanced Delivery System, Precision Targeting, Early Detection, and Increased Efficacy. Examples of some diseases which are already controlled by Nanotechnology are: Silver nanoparticles have shown antifungal inhibition of *Alternaria alternata, Sclerotinia sclerotiorum, Rhizoctonia solanai, Chitosan* nanoparticle exhibit antifungal activity in vitro and could protect finger millet plants from blast disease caused by *Pyricularia grisea*, small size of the active ingredient (1-5 nm) of silver effectively controls diseases like Powdery mildew. Nanotechnology can bring several changes and can be replaced by the chemical fertilizers and the changes are: Early Detection and Monitoring, Sustainable Solutions, Customized Solutions, Precision Targeting.

Keywords: Nanotechnology, Nanoparticles, Plant Disease Management.

Introduction

Plant disease is important challenge faced by agriculturist in plant produced globally. It is estimated as the 20-40% loss per year. Current disease management relies heavily on the application of chemicals such as fungicides, bactericides and nematicides. In spite of many advantages, like high availability, fast action, and reliability, pesticides have harmful side effect It is estimated that 85-90% of applied pesticides are lost during or after the application.

The term "Nanotechnology" was coined by Taniguchi in 1974. It is a science that deals with synthesis and application of nano size particles 1-100nm.According to the US Environmental Protection

Agency, nanotechnology is explained as the examination of comprehending and managing matter at scales approximately 1-100 nm (Concha-Guerrero et al., 2017). Nanotechnology impacts on development have a lot of application such as production of energy, improve agriculture production, drinking water treatment and disease diagnosis. The utilization of nanotechnology in plant disease management, diagnosis, and genetic transformations is still in its infancy and has only begun to be explored in the plant pathology literature. As a result of nanoparticles small size and large surface area to volume ratio, they can be reactive and bind, absorb, and carry compounds such as small-molecule drugs, DNA, RNA, proteins, and probes with high efficiency. The nanoparticles are then harvested, characterized, and available for use. This single-step green-synthesis process is rapid, can be conducted at ambient temperature and pressure, and is readily scalable. Several species in the plant-pathogenic genera of *Fusarium, Aspergillus, Verticillium,* and *Penicillium* have been employed to biosynthesize nanoparticle.

Green synthesis of nanoparticles could have great impact on their use in organic production disease management if the certifying governing boards of organic growers decide to approve the green synthesis of these materials as a treatment option.

History:

The history of nanotechnology in plant disease management spans several spans several decades, with research efforts intensifying in recent years. Some points are given below includes:

Early Exploration (1990s-2000s): In the early stages, researchers began exploring the potential of nanotechnology for applications, including plant disease management. Initial studies focused on investigating the antimicrobial properties of nanomaterials and their potential for controlling plant pathogens.

Nano-Enabled Delivery Systems (2000-2010s): During this period, researches started developing nano-enabled delivery systems for delivering pesticides, fungicides, and biocontrol of plant pathogens. Nanoparticles-based biosensors and nanomaterial-based platforms have been investigated for detecting viruses, bacteria, and fungi in plants, enabling early disease diagnosis and management.

Diagnostic Tools and Sensors (2010s-present): Advances in nanotechnology have led to the development of nanoscale diagnostic tools and sensors for rapid and sensitive detecting of plant pathology. Nanoparticle-based biosensors and nanomaterial-based platforms have been investigated for detecting viruses, bacteria, and fungi in plants, enabling early disease diagnosis and management.

Bio-Nanotechnology (2010s-Present): Researchers have increasingly focused on the intersection of nanotechnology and biotechnology, known as bio-nanotechnology, to develop innovative solutions for plant disease management. This includes using nanomaterials for delivering RNA interference (RNAi) molecules to silence genes in plant pathogens or enhance plant resistance to diseases.

Field Trials and Commercialization (Present): Some nanotechnology-based products for plant disease management have reached the stage of field trials and commercialization. These products may include nano-formulations of pesticides, fungicides, or biocontrol agents designed to improve disease control while minimizing environmental impacts. While the field of nanotechnology in plant disease management is still evolving, these milestones demonstrating the growing interest and potential of nanotechnology to address challenges in agriculture and enhance crop protection against diseases. Ongoing research and development efforts aim to further advance the application of nanotechnology for sustainable and effective disease management in the future.(Malerba and Cerana 2016): They summarized potential mechanisms that lead to the antimicrobial effects of chitosan, such as agglutination, disruption of the cell membranes inhibition of H -ATPase activity, inhibition of toxin production and microbial growth, inhibition of the synthesis of messenger RNA and proteins, and blockage of nutrient flow. Antiviral effects have been observed in beans against Bean Mild Mosaic Virus and in tobacco against Tobacco Mosaic Virus and Tobacco Necrosis Virus. Loading insecticides into nanoparticles first started in the year 2000s. Since then, conventional insecticides (27 studies) and bioactive compounds with insecticidal properties (13 studies) have been conducted with a range of essential oils (not included in Insecticide Resistance Action Committee (IRAC) classification.(Kumar et al.) found that okra bhindi plants sprayed with sodium alginate-encapsulated imidacloprid were just as effective as imidacloprid alone. (Song et al.) treated *Brassica chinese* with silica-encapsulated chlorfenapyr to achieve similar or more effective control against the Diamondback Moth (*Plutella xylostella)* over a three-day period. (Meredith et al.) observed a decreased in toxicity effects on zebrafish with hollow polymeric shell nanoparticle-encapsulated alpha-cyhalothrin, and the larger micron -sized particles of the same composition, when compared to the unformulated insecticide *alpha*-cyhalothrin starting in 1997 initial studies on nanofungicides were conducted on incorporated fungicides into solid wood .(Chidambaram2016) converted rice husk waste into nanosized particles, and loaded them with 2,4-D. They found that nanoparticle-loaded 2, 4-D had better herbicidal activity than 2, 4-D alone against the target plant (Brassica sp.).Li-Byarlay used siRNA loaded onto perfluorocarbon nanoparticles to study DNA methylation in honeybees.(Mitter et al.) tested an RNAi\nanoparticle topical delivery platform called BioClay to protect plants against viruses 20 days post-spray application. (Zhao et al.) Studied the pesticide levels over 48 day's post-application of their developed nano formulation. The history of using nanoparticles to control plant diseases is relatively recent, but is research in this area has made significant progress in addressing various plant pathogens.

Here's an overview: **Fungal Diseases:** Nanoparticles have been explored for controlling fungal diseases in plants. Studies have investigated the use of nanoparticles, such as silver nanoparticles, copper nanoparticles, and zinc oxide nanoparticles, for their antifungal properties. These nanoparticles have shown efficacy against a range of fungal pathogens, including powdery mildew, rusts, and fusarium wilt.

Bacterial Diseases: Nanoparticles have also been studied for controlling bacterial diseases in plants. Research has focused on using nanoparticles, such as silver nanoparticles and copper nanoparticles, to inhibit the growth of bacterial pathogens and prevent disease development. These nanoparticles can disrupt bacterial cell membranes, leading to cell death and disease suppression.

Viral Diseases: While controlling viral diseases in plants presents unique challenges, nanoparticles for delivering antiviral compounds or RNA interference (RNAi) molecule to plants, which can inhibit viral replication and reduce disease symptoms.

Nematode Infestations: Plant-parasitic nematodes cause significant damage to crops worldwide. Nanoparticles have been investigated for controlling nematode infestations in plants. Studies have explored the use of nanoparticles, such as carbon nanotubes and metal nanoparticles, for their nematocidal properties, which disrupt nematode physiology and reduce nematode populations in soil.

Abiotic Stress: In addition to biotic stressors, nanoparticles have been studied for mitigating abiotic stresses that can predispose plants to diseases. Nanoparticles have been explored for enhancing plant tolerance to stresses such as drought, salinity, and heavy metal toxicity, thereby indirectly reducing disease incidence.

Objective/ Aim of Nanotechnology in Plant Disease Management:

The aim of nanotechnology in plant disease management is to develop advanced and effective strategies to combat plant diseases while minimizing environment Impact and promoting sustainable agriculture.

Key aim include:

Improved Disease Control: Develop novel methods and technology that enhance the control of plant diseases, including fungal, bacterial, viral, and nematode pathogens to reduce crop losses and ensure food security.

Precision Targeting: Achieve precise targeting of plant pathogens while minimizing harm to beneficial organisms and the environment, thereby reducing the need for broad-spectrum pesticides and fungicides.

Enhanced Delivery Systems: Design nano-enabled delivery systems for delivering biocontrol agents, pesticides, and fungicides to plants, improving their efficacy and reducing the amount needed for disease management.

Early Detection and Diagnosis: Develop nanotechnology-based sensors and diagnostic tools for the rapid and sensitive detection of plant pathogens, enabling early disease diagnosis and timely intervention to prevent disease outbreaks.

Sustainable: Promote sustainable agriculture practices by reducing the reliance on chemical pesticides and fungicides through the development of environmentally friendly nanotechnology – based solutions that minimize adverse effects on ecosystems and human health.

Customized Solutions: Tailor nanotechnology-based approaches to specific plant diseases, environmental conditions, and agricultural practices, allowing for personalized and optimized disease management strategies.

Integration with Precision Agriculture: Integrate nanotechnology with other precision agriculture technologies, such as remote sensing, data analytics, and automation, to create holistic disease management systems that optimize resources use and maximize crop productivity while minimizing environmental impact.

Methods of Nanotechnology in Plant Disease Management:

Nanotechnology offers a multifaceted approach to plant disease management, leveraging advanced materials and delivery systems to enhance the effectiveness of traditional methods. Here's a summary of the key approaches you've outlined:

Nanoparticles as Antimicrobial Agents: Metal-based nanoparticles (e.g., silver, copper, zinc, titanium dioxide) have demonstrated strong antimicrobial properties against a broad spectrum of plant pathogens. These nanoparticles can be formulated into sprays or coatings that directly inhibit pathogen growth.

Nanoparticle-Based Delivery Systems: Nanocarriers facilitate the more effective delivery of pesticides, fungicides, and antimicrobial agents. Nanoencapsulation not only protects the active ingredients from degradation but also improves their stability and enables controlled release, thereby enhancing efficacy and reducing environmental impact.

Nano Biosensors for Disease Detection: Nanotechnology enhances the sensitivity and specificity of biosensors for early detection of plant diseases. These nano biosensors can identify specific biomarkers or DNA sequences associated with pathogens, enabling rapid and accurate disease diagnosis.

Nanomaterials for Plant Immunity Enhancement: Certain nanomaterials, such as carbon nanotubes and nano clays, have shown potential in enhancing plant immunity. They can induce systemic resistance and modulate defense mechanisms, including the production of reactive oxygen species (ROS) and defense-related enzymes, thereby making plants more resilient to pathogens.

Nanoparticle-Mediated Gene Delivery: Nanoparticles can act as carriers for gene delivery into plant cells, enabling genetic engineering to enhance disease resistance. This approach can introduce genes encoding antimicrobial peptides, pathogen-derived resistance genes, or RNA interference (RNAi) constructs targeting vital pathogen genes.

Nano Fertilizers for Improved Plant Health: Nanotechnology improves nutrient delivery through nano formulations of fertilizers, which exhibit better solubility, stability, and uptake efficiency. By promoting stronger and healthier plants, these fertilizers indirectly contribute to disease management by reducing plant susceptibility to infections.

Smart Nanomaterials for Controlled Release: Stimuli-responsive nanomaterials can be designed to release active compounds in response to specific triggers such as pH changes, temperature, or the presence of pathogens. This controlled release optimizes the effectiveness of disease management agents while minimizing environmental impact and off-target effects.

Nanotechnology for Soil Health Management: Nanomaterials can be employed to manage soil health by targeting soil-borne pathogens. Nano-enabled formulations of biocontrol agents or organic amendments can suppress harmful pathogens, enhance beneficial microbial communities, and improve soil fertility, ultimately reducing disease incidence in crops.

These approaches represent the cutting edge of plant disease management, offering sustainable and efficient solutions to protect crops and improve agricultural productivity.

Types of Nanotechnology used in Plant Disease Management:

An average 20-40% global losses occur only due to pest and pathogens. Currently, plant disease is managed through an efficient use of fungicides and insecticides. For example, Nanoparticles could be employed directly as such or as transporters for currently known pesticides or further active ingredients including double-stranded RNA (dsRNA) for their use as spray application, drenching/soaking onto seeds and over other tissues (root and leaves).

Magnetic Nanoparticles: As a diagnostic material Magnetic nanoparticle can also be used as diagnostic tool as it attaches the biological tissues or DNA. Magnetic nanoparticles including super magnetic iron oxide and quantum dots can be used as a disease diagnostic tool as both of these to be attached with the hyphae of fungi.

Quantification of *Meloidogyne hapla* from mineral soils were performed by adding the superparamagnetic iron oxide nanoparticles to the extraction lysate to maximize the DNA yield.

Silver Nanoparticles: The silver nanoparticles are applied before the penetration and colonization of fungal spores within the plant tissues. The small size of the active ingredient (1-5nm) of silver effectively controls diseases like *Powdery* Mildew. The in vitro and in vivo evaluation of antifungal action of silver nanoparticles on *Bipolaris sorokiniana* and *Magnaporthe grisea* showed decreased disease development by plant pathogenic fungi.

Silica nanoparticle: Silica is known to be observed into plant to increase the disease resistance and stress resistance. Silica nanoparticles can be easily synthesized with controlled size and shape, it promotes the physiological activity and growth of plants and also induces the diseases and stress resistance in plants. Mesoporous silica nanoparticles can be targeted delivery of DNA and chemicals. The shell structure of porous hallow silica nanoparticles protect the active molecule inside the nanoparticles against degradation by UV light. This method has been successfully introducing DNA into plants such as corn and tobacco. Silica-Silver nanoparticles reportedly have antifungal activity against *Botrytis cinerea, Rhizoctonia solani, Collectotrichum gloeosporioides.*

Chitosan nanoparticle: Chitosan nanoparticle exhibited antifungal from Blast disease caused by *Pyricularia grisea.* Chitosan nanoparticles were reported to be effective against plant pathogenic fungi and bacteria effecting tomatoes. The growth inhibitory effects were maximum in *Fussarium oxysporum* fallowed by *P. capsici, Xanthomonas compestrispv, Vesicatorio* as well as *Erwinia carotovora* was inhibited.

Copper nanoparticles: Broad spectrum antimicrobial properties copper- based compounds has been used for centuries to manage plant pathogens. The first metal-based fungicides used in plant disease management comprises of copper and copper containing hydroxide, Bordeaux mixture etc. to control bacterial blight in pomegranate which continues today. Bordeaux mixture that is composed of lime, copper sulphate and water which was used to control grapevine downy mildew disease caused by *Plasmopara viticola* an oomycetes pathogen. It was discovered that nanoparticle can be effective in controlling bacterial disease, namely leaf spot of mung and Bacterial leaf blight in rice. Copper nanoparticles at concentration of 200 mg/L were inhibitory to *Pseudomonas srringae* whereas the particle was not biocidal against *Rhizobium spp.* and *Trichoderma harzinum* in comparison to copper chloride.

Gold nanoparticles: Gold nanoparticles oligonucltideprodes are hybridized with the complementary DNA, which stabilizes gold nanoparticles against aggregation (retaining the native pink color of the colloidal gold). In the absence of complementary DNA, the solution turns purple because the aggregation of gold nanoparticles leads to the shift in absorbance peak towards a longer wavelength. Gold nanoparticles features agglomeration related to color production that was used in detection of pesticide. Gold nanoparticle-based optical immunosensors have been developed for detection of Karnal bunt disease in wheat.

Zinc nanoparticles: Mechanism of action of nano-ZnO derived from zinc nitrate on important pathogen Aspergillus fumigatus demonstrated that it made cell wall deformity by hydroxyl and superoxide radicals mediated in fungal and finally led to death due to high energy transfer. ZnO nanoparticles (ZnO NPs) were also reported to be effective against two postharvest pathogenic fungi (*Botrytiscinerea* and *Penicillium expansum),* thus contributing in agriculture and food safety application. ZnO nanoparticles prevented the development of conidiophores and conidia of *P. expansum,* which eventually lead to death of fungal hyphae.

Nano-biosensors: They allow the detection of contaminants such as pests, microbes, plant stress and nutrient content due to insect or pathogen pressure. The nanomaterials used for biosensors construction include metal and metal oxide nanoparticles, quantum dots, carbon nanomaterials such as carbon nanotubes and graphene. Controlled Environmental Agriculture (CEA) can be improved by use of nano sensors enhancing the aptitude microbial or chemical composition of crop. Nano sensors may be used to diagnose soil disease caused by infecting soil microorganisms such as virus bacteria and fungi via quantitive measurement of different oxygen consumption in the respiration of good and bad microbes in the soil.

Nano- Pesticides: A nano pesticide is a type of pesticide formulated at the nanoscale, typically using nanoparticles. These nanoparticles are extremely small, often measuring less than 100 nm in size. Nano pesticides can contain various active ingredients, such as insecticides, fungicides, or herbicides, which are encapsulated or attached to nanoparticles.

Some targeted insect pest which are controlled by nano-pesticide:

Aphids: These sap-sucking insects can cause significant damage to fruits, vegetables, and ornamental plants. Nano-pesticides can be designed to disrupt their feeding habits and reproductive cycles.

Whiteflies: Whiteflies feed on plant sap and can transmit plant viruses. Nano-pesticides can target them at various life stages, reducing their ability to reproduce and spread diseases.

Thrips: Thrips are known for puncturing plant tissues and sucking out cell contents, leading to damage on leaves, flowers, and fruits. Nano-pesticides can be used to effectively reduce their populations.

Mosquitoes: While not directly related to crop damage, mosquitoes are significant pests in urban and rural areas due to their role in transmitting diseases such as malaria, dengue fever, Zika virus, and West Nile virus. Nano-pesticides can be utilized to target mosquito larvae or adult mosquitoes, reducing their populations.

Caterpillars: The larvae of moths and butterflies, commonly known as caterpillars, can cause severe damage to crops by feeding on leaves, stems, and fruits. Nano-pesticides can offer targeted control, minimizing crop loss.

Beetles: Beetle pests, including the Colorado potato beetle, flea beetles, and weevils, can devastate various crops. Nano-pesticides can be engineered to target these pests specifically, reducing their impact on agriculture.

Mites: Plant-feeding mites, such as spider mites and rust mites, can cause significant damage by feeding on plant tissues and transmitting diseases. Nano-pesticides can be effective in controlling mite infestations.

Ants: Certain ant species can be agricultural pests, either by tending to aphids or other honeydew-producing insects or by directly damaging crops. Nano-pesticides can help manage ant populations and mitigate their impact on agriculture.

Nano-pesticides offer precise targeting, enhanced efficacy, and reduced environmental impact compared to conventional pesticides, making them a valuable tool in integrated pest management strategies.

Advantages of Nanotechnology in Plant Disease Management:
Nanoparticles offer several advantages in plant disease management:

Enhanced Delivery: Nanoparticles can carry and deliver pesticides, fungicides, or other disease-fighting agents more efficiently to target plant tissues, improving effectiveness.

Reduced Environmental Impact: They allow for precise targeting, reducing the amount of chemicals needed and minimizing environmental contamination.

Increased Stability: Nanoparticles can protect active compound from degradation, ensuring prolonged efficacy.

Improved Adhesion: They can adhere better to plant surfaces, increasing retention and reducing runoff.

Enhanced Penetration: Nanoparticles can penetrate plant tissues more effectively, reaching pathogens in deeper layers.

Slow Release: Controlled released mechanisms can be incorporated, providing sustained protection over time.

Biocompatibility: Many nanoparticles are biocompatible and pose minimal risk to plants and the environment.

Disadvantages of Nanotechnology in Plant Disease Management:
Toxicity Concerns: Some nanoparticles may have adverse effects on plants, soil organisms, or beneficial insects, raising concerns about unintended ecological impact.

Regulatory Challenges: The novel nature of nanomaterials can crete regulatory hurdles regarding their safety and environmental impact, leading to delays in approval and adoption.

Cost: Nanotechnology based solutions can be expensive to develop and produce, potentially limiting their accessibility to farmers, especially in low-income regions.

Limited Understanding: The long-term effects of nanoparticles on soil health, plant physiology, and ecosystem dynamics are not fully understood, necessitating further research. **Risk of Resistance:** Continuous use of nanoparticle-based treatments may lead to the development of resistance in pathogens, similar to conventional pesticides and fungicides. **Environmental Persistence:** Nanoparticles may persist in the environment for extended periods, raising concerns about bioaccumulation and ecosystem disruption.

Public Perception: There may be public skepticism or resistance to the use of nanotechnology in agriculture due to concerns about potential unknown risks and unintended consequences. **Future Outlook of Nanotechnology in the field of Plant Protection:**

Nanotechnology can provide solutions for agriculture applications and has the potential to revolutionize the existing technologies used in pest management. Development of nano pesticides can offer unprecedented advantages like: Improved solubility of poorly water-soluble pesticides. Increased bioavailability and efficacy of pesticides when loaded onto nanoparticles and reduced pesticide toxicity. Enhanced shelf-life and controlled delivery of actives. Target-specific delivery of the active molecules and pH dependent release. Smart delivery of RNAi molecules for disease management. Nanoparticles as carriers to slow down degradation of active molecules and improve the formulations' UV stability and rain-fastness. Nanopesticides to improve the selective toxicity and overcome pesticide resistance.

Conclusion

The technologies presently employed in numerous fields, including as agriculture, could be completely transformed by nanotechnology. In conclusion, material scientist and biological need to work closely and bring in complementary expertise from various fields, in order to have a deeper understanding of the fundamental interaction mechanism in a complex bio-nano system. Nanotechnology can provide solution for agriculture applications and has the potential to revolutionize the existing technology used in the disease management. Development of Nano pesticides can offer unprecedented advantages like.Increased bioavailability and efficiency of pesticides when loaded onto nanoparticles can reduced toxicity, Enhanced shelf-life and controlled delivery of actives. Nanotechnology and Nano scale science clearly possess a great role in improved and innovative solutions. It is also important to select a reliable and reproducible system to conduct biocompatibility and efficiency studies at the cell, organism, and pest-host ecosystem levels, aiming for close-to field conditions as possible. Some of the particular plant disease can also be controlled by using this. It can be replaced with the chemical insecticides, fungicides and pesticides which infects the soil. There is a need of in-depth research in this field about to control the plant diseases and to check their phytotoxicity levels.

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ISSN : 2583-0910
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Peer reviewed
monthly newsletter

Article ID : 04/IX/19/0924

RUST DISEASES: COMPLEX LIFE CYCLES AND VIRULENCE OF PUCCINIALES

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Abstract

Rust fungi, belonging to the order *Pucciniales*, are significant plant pathogens responsible for rust diseases, which have posed a challenge to agriculture since ancient times. These fungi are obligate biotrophs, requiring host plants to complete their complex life cycles, which can include up to five distinct spore types and often necessitate two different host species. The life cycle stages involve both gametothallus and sporothallus hosts, contributing to disease epidemics through rapid asexual reproduction. Rust fungi demonstrate considerable evolutionary adaptability, facilitated by their complex life cycles, sexual and asexual reproduction, and the gene-for-gene interaction model, which drives virulence evolution. Recent advances in genomic and molecular research are shedding light on the mechanisms behind host adaptation and virulence. Understanding these processes is critical for developing effective strategies to combat rust diseases and protect vital agricultural crops like wheat, soybean, and coffee from these pervasive pathogens.

Key words: Rust fungi, *Pucciniales*, Plant pathogens, Virulence and Host adaptation

Introduction

Fungi of the order *Pucciniales*, commonly known as rust fungi, are significant plant pathogens responsible for rust diseases. These diseases have plagued agriculture since ancient Greek and Roman times and continue to be a major challenge today, affecting key crops like wheat and soybean. Rust fungi are obligate plant biotrophs, meaning they cannot complete their life cycles without their host plants. Although some species have been cultured *in vitro*, only limited mycelium production has been achieved, making host plant colonization essential for experimental studies (Salcedo *et al*., 2017).

Taxonomy and Genomic Studies

The order *Pucciniales* is one of the largest in the Kingdom Fungi, with over 7,000 species categorized into seven suborders, 18 families, and approximately 170 accepted genera. The twentieth century saw significant research efforts focused on rust fungi using microscopy, biochemistry, and molecular and genetic approaches. In the past decade, genome sequencing and large-scale omics approaches have been applied to rust fungi, offering unprecedented opportunities to explore host adaptation and virulence mechanisms (Bushnell and Roelfs 1984). Here are some examples:

1. Wheat Stem Rust: *Puccinia graminis* f. sp. *tritici*
2. Cedar-Apple Rust: *Gymnosporangium juniperi-virginianae*
3. Soybean Rust: *Phakopsora pachyrhizi*
4. Coffee Leaf Rust: *Hemileia vastatrix*
5. Bean Rust: *Uromyces appendiculatus*

6. White Pine Blister Rust: *Cronartium ribicola*
7. Hollyhock Rust: *Puccinia malvacearum*
8. Pear Trellis Rust: Gymnosporangium sabinae
9. Yellow Rust or Stripe Rust: *Puccinia striiformis* f. sp. *tritici*
10. Chrysanthemum White Rust: *Puccinia horiana*

Complex Life Cycle of Rust Fungi

Rust fungi exhibit one of the most complex life cycles in the Kingdom of Fungi and among eukaryotes in general. They alternate between generations and produce up to five distinct spore types at specific stages. The majority of rust fungi require two different host plants to complete their life cycle, a phenomenon known as heteroecism. These fungi are found worldwide and can disperse spores over long distances, including intercontinental movements. For instance, wheat stem rust (*Puccinia graminis* f. sp. *tritici*) isolates in Australia are closely related to those in South Africa, likely due to wind-borne spores travelling across the Indian Ocean (Aime *et al*., 2017).

Infection of the Gametothallus Host

Infection of the gametothallus (Ga) host begins when monokaryotic basidiospores adhere to the host surface, penetrate the cuticle, and form vesicles within the invaded cells. This is followed by the production of intercellular infection hyphae and haustoria, which sustain nutrient acquisition and hyphal growth within the host tissue. The Ga-host infection stage involves spermatization, where spermatia are exchanged and fertilization occurs. This process leads to the formation of dikaryotic aeciospores, which cannot reinfect the Ga-host but can infect the sporothallus (Sp) host (Hiratsuka and Cummins 1963).

Infection of the Sporothallus Host

The infection stage on the Sp-host is responsible for disease epidemics in crops. Aeciospores from the Ga-host land on the Sp-host, where they germinate and form urediniospores. Urediniospores are unique because they can reinfect the same host, leading to rapid and widespread epidemics. This asexual multiplication can continue during favorable conditions, enabling clonal populations to persist in the absence of a Ga-host (Staples 2000).

Overwintering and Teliospore Formation

The final stage of the rust fungi life cycle involves the formation of teliospores on the Sp-host. Teliospores are thick-walled, dormant spores that form in response to environmental cues and potentially host signals. Upon the return of favorable conditions, teliospores germinate, undergo meiosis, and produce haploid basidiospores, which can then infect the Ga-host. This stage is critical for the survival and continuation of the rust fungi life cycle (Hacquard *et al*., 2013).

Evolution and Adaptation

Rust fungi have evolved complex mechanisms to adapt to their hosts and environments. The alternation of generations on different hosts allows for significant evolutionary plasticity. Sexual reproduction generates new combinations of alleles, enabling rapid adaptation, while asexual reproduction allows for the proliferation of highly fit genotypes. The separation of sexual and asexual phases on different hosts influences the evolutionary potential of rust fungi (Aime *et al*., 2017).

Molecular Mechanisms of Virulence

The evolution of virulence in rust fungi follows the gene-for-gene concept, where two virulence (Vir) alleles are required for the emergence of new virulent phenotypes. During asexual propagation, mutations in avirulence (Avr) genes or chromosomal exchange can result in virulence. Additionally, somatic fusion of rust strains can lead to the convergence of Vir alleles. Sexual recombination, through the mating of two genotypically distinct rust isolates, can also bring together two Vir alleles, further enhancing virulence (Hubbard *et al*., 2015).

Host Adaptation

Host adaptation involves genetic changes that enhance a pathogen's ability to overcome host defences and successfully colonize the host plant. This adaptation can occur through various mechanisms, such as mutations, genetic recombination, and horizontal gene transfer. Rust fungi develop specialized traits that facilitate attachment to host cells, evasion of the host immune system, and manipulation of host physiology for their benefit (Zhao *et al*., 2021).

Conclusion

Rust fungi of the order *Pucciniales* represent a significant challenge to global agriculture due to their complex life cycles, ability to disperse over long distances, and rapid adaptation to different hosts. Ongoing research, particularly in the areas of genomics and molecular biology, continues to uncover the intricate mechanisms that drive rust fungi evolution and virulence. Understanding these processes is crucial for developing effective strategies to manage rust diseases and protect essential crops.

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ISSN : 2583-0910
Agri-India TODAY
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monthly newsletter

Article ID : 04/IX/20/0924

SYNOPTIC VIEW ON MARINE SOURCES OF ANTIOXIDANTS AND THEIR ROLE IN HUMAN HEALTH

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ABSTRACT:
Marine organisms are a rich source of natural antioxidants, which are crucial to human health by neutralizing harmful free radicals linked to chronic diseases such as cancer and cardiovascular disorders. Marine species, including macroalgae, sponges, and shellfish, produce diverse antioxidant compounds like carotenoids, polyphenols, and tocopherols. These compounds protect against oxidative stress and exhibit anti-inflammatory properties, making them valuable in drug discovery and therapeutic applications. The sustainable harvesting of these marine antioxidants offers promising avenues for enhancing human health and addressing oxidative stress-related disorders.

Keywords: Natural antioxidants, Marine sources, Scavenging, Bioactive compounds, Phenolic compounds, Health care.

INTRODUCTION:
An antioxidant is a substance that protects cells from damage caused by free radicals such antioxidants are from two sources synthetic and natural. Natural substances are now widely employed around the world to treat human diseases and health conditions. Throughout history, plants have been the principal source of numerous medicinal medicines. However, throughout the years, much attention has been paid to the tremendous biodiversity of life in seas, which has proven to be an exceptional repository of unique bioactive compounds with divergent structural and chemical properties and a source of inspiration for new drug creation (Vasarri & Degl'Innocenti, 2022). While exploring the sea and marine biodiversity it gives many natural health benefit products (Sansone & Brunet, 2020).

MARINE SOURCE OF ANTI-OXIDANTS:
The source of antioxidants in marine world includes a wide range of organism which include sponges, seaweeds, bacteria, and microalgae and it is presented in Figure 1. These organisms showcase various bioactive compounds such as polyphenols, carotenoids, and sulfated polysaccharides. Recent studies show the potential for marine biota to replace synthetic antioxidants in pharmaceuticals and nutraceuticals, stressing their significance in health promotion and illness prevention (Vladkova *et al*., 2022).

Sponges:
Marine sponges are high in bioactive chemicals, particularly terpenes, which have potent antioxidant properties. A thorough analysis revealed 17 terpene compounds with strong antioxidant properties, as measured by methods such as DPPH scavenging and reactive oxygen species detection. These antioxidants may play an important role in human health by countering oxidative stress and inflammation, potentially leading to therapeutic uses in treating chronic diseases (Martignago *et al*., 2023).

Seaweeds:
Seaweed is high in antioxidants, particularly fucoxanthin, a pigment found in brown algae. Fucoxanthin is important for human health because it acts as a free radical scavenger, reduces oxidative stress, and may lower the risk of chronic diseases such as cancer and diabetes. Other antioxidants found in seaweed include phenolic compounds and polysaccharides, which help to reduce inflammation and improve the immune system (Cornish & Garbary, 2010; Michalak *et al.*, 2022).

Bacteria:
Several marine microorganisms have been discovered to produce antioxidants that can bring health benefits. Kocuria marina - Produces antioxidant molecules called Ser-Ser-Gln to decrease DPPH free radicals (Vladkova *et al.*, 2022). It is Isolated from marine sources in the Gulf of Mannar Bay of Bengal, India. Probiotic bacteria- have their own antioxidant enzymatic systems, including SOD superoxide dismutase, CAT catalase, and GPx glutathione peroxide (Wang *et al.*, 2017). SOD catalyzes the dismutation of superoxide ($O2^-$) into oxygen and hydrogen peroxide, while CAT and GPx convert hydrogen peroxide to water and oxygen. Probiotic bacteria can boost the host's antioxidant system and reduce radical production, lowering oxidative stress and related diseases (Vladkova *et al.*, 2022).

Microalgae:
Microalgae contain a variety of antioxidants, including carotenoids (e.g., astaxanthin and β-carotene), phenolic compounds, and tocopherols. These antioxidants play a crucial role in human health by scavenging free radicals, reducing oxidative stress, and lowering the risk of chronic diseases like cancer and cardiovascular disorders. Astaxanthin, for example, has potent anti-inflammatory and neuroprotective properties, contributing to overall health especially skin health (Davinelli *et al.*, 2018; Coulombier *et al.*, 2021).

S. No	Organism	Antioxidant compound	Role of those compounds in human health	Reference
1.	Sponges	Terpene	Terpenes can modulate immune responses, alleviate pain	(Martignago *et al.*, 2023)
2.	Seaweed	Fucoxanthin	fucoxanthin aids in the prevention of chronic diseases such as obesity, and diabetes, and reduces fat accumulation	(Cornish & Garbary, 2010; Michalak *et al.*, 2022)
3.	Bacteria	Ser-Ser-Gln SOD superoxide dismutase, CAT catalase, and GPx glutathione peroxide	SOD prevents cellular damage. CAT reduces oxidative stress. GPx is vital for cellular defense against oxidative damage	(Vladkova *et al.*, 2022; Wang *et al.*, 2017)

S. No	Organism	Antioxidant compound	Role of those compounds in human health	Reference
4.	Microalgae	astaxanthin and β-carotene, phenolic compounds, and tocopherols	Astaxanthin-Reduce inflammation β-carotene-eye health phenolic compounds-Reduce the risk of cancer and heart diseases and tocopherols-support immune health	(Davinelli *et al*., 2018; Coulombier *et al*., 2021)

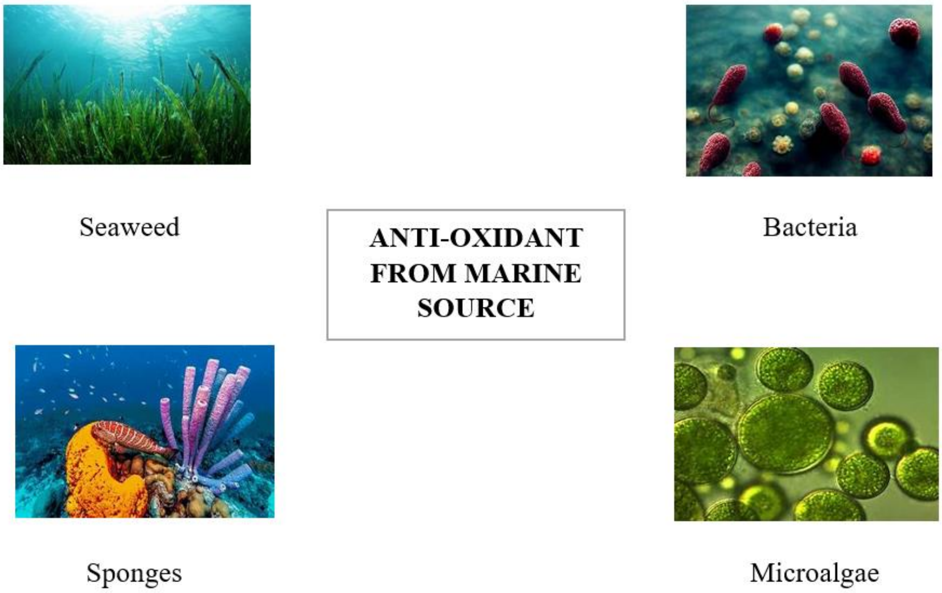

Fig. 2 Anti-oxidants from marine sources

INDUSTRIAL APPLICATIONS:

Marine antioxidants are gaining popularity for their potential use in medicines, cosmetics, and food preservation. Marine-derived antioxidants, such as carotenoids and polyphenols, have anti-inflammatory and anticancer characteristics, making them potential therapeutic candidates (Vasarri & Degl'Innocenti, 2022; Vladkova *et al*., 2022). These antioxidants are employed in cosmetics for their anti-aging properties and skin protection, which improves product efficacy. Marine antioxidants act as natural preservatives in food preservation, prolonging shelf life while maintaining quality in response to customer demand for clean-label products. The combination of antioxidant and antibacterial characteristics is especially useful in tackling antibiotic resistance (Vladkova *et al*., 2022).

FUTURE ASPECTS:

Future research on marine antioxidants demonstrates their promise in drug development and health applications. Marine species, such as algae, sponges, and shellfish, are being studied for their distinct bioactive chemicals, which have antioxidant and anti-inflammatory characteristics. These chemicals may address issues such as antibiotic resistance and chronic diseases connected to oxidative stress. Innovative extraction technologies and the use of wastes from marine industries are projected to improve the quantity and quality of these antioxidants, paving the path for industrial uses in pharmaceuticals and dietary supplements (Vasarri & Degl'Innocenti, 2022; Vladkova *et al.,* 2022).

CONCLUSION:

Marine sources of antioxidants represent a promising frontier in health and nutrition. The extraction and application of these marine-derived compounds are gaining attention for their therapeutic potential, emphasizing the importance of marine biodiversity in developing new health-promoting products. The continued investigation into marine antioxidants may lead to novel health products and strategies to combat oxidative stress-related diseases, highlighting the importance of marine biodiversity in future health solutions.

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ISSN : 2583-0910
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Peer reviewed
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Article ID : 04/IX/21/0924

VALUE-ADDED PRODUCTS FROM MEDICINAL MUSHROOMS: INNOVATIONS AND APPLICATIONS

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Abstract

Medicinal mushrooms, such as Cordyceps, Ganoderma (Reishi), Hericium (Lion's Mane) and Turkey Tail, are transforming the health and wellness industry through innovative value-added products. Historically revered in traditional medicine, these fungi are now featured in dietary supplements, functional foods, skincare products, and more. Cordyceps enhances energy and athletic performance, Reishi promotes stress relief and longevity, Lion's Mane supports cognitive function, and Turkey Tail boosts immune health. This article explores the diverse applications of these mushrooms, including energy supplements, calming teas, cognitive enhancers, and immune-boosting products. Additionally, the synergy of combining multiple medicinal mushrooms into single formulations and their incorporation into superfoods and skincare highlight their expanding role in modern wellness. As research and consumer interest grow, medicinal mushrooms continue to offer sustainable and effective solutions for health and beauty, bridging ancient traditions with contemporary needs.

Keywords: Medicinal mushroom, Cordyceps, Ganoderma, Hericium, Turkey Tail, Value addition

Introduction

In recent years, medicinal mushrooms have burst onto the wellness scene, celebrated for their impressive health benefits and wide-ranging applications. Far from being just a culinary delight, mushrooms like Cordyceps, Ganoderma (Reishi), Hericium (Lion's Mane) and Turkey Tail have become the cornerstone of a growing industry focused on value-added products. These fungi are now being harnessed in various forms, from dietary supplements to skincare products, each promising a unique blend of health and vitality. In this article, we explore the fascinating world of medicinal mushrooms and the innovative value-added products that are transforming the wellness industry.

Mushrooms have been used in traditional medicine for thousands of years, particularly in Asia, where they are revered for their healing properties. Today, modern science is catching up with ancient wisdom, and research is increasingly supporting the health benefits of these fungi. Medicinal mushrooms are rich in bioactive compounds, including polysaccharides, beta-glucans, triterpenoids and antioxidants, which contribute to their therapeutic effects. These properties make them ideal candidates for a wide range of value-added products aimed at boosting health and wellness.

Cordyceps: The Energy Booster

Cordyceps militaris is a medicinal mushroom that has gained fame for its ability to enhance energy levels and athletic performance. Traditionally used in Chinese medicine, Cordyceps is known for its potential to increase the body's production of adenosine triphosphate (ATP), which is essential for delivering energy to muscles.

Value-Added Products:

- **Energy Supplements:** Cordyceps is commonly found in energy-boosting supplements, often in the form of capsules or powders. These products are marketed to athletes and individuals seeking to improve stamina and reduce fatigue. Cordyceps supplements are often combined with other adaptogenic herbs to create powerful blends that support physical endurance and mental clarity.
- **Functional Beverages:** The popularity of Cordyceps has extended to the beverage industry, where it is used in energy drinks and herbal teas. These drinks offer a natural alternative to caffeine-based beverages, providing sustained energy without the jittery side effects.
- **Pre-Workout Formulas:** Cordyceps is increasingly featured in pre-workout supplements, where its ability to improve oxygen utilization and enhance endurance makes it a valuable ingredient for fitness enthusiasts.

Ganoderma (Reishi): The Stress Reliever

Ganoderma lucidum, commonly known as *Reishi,* is often referred to as the "Mushroom of Immortality" due to its long-standing reputation for promoting longevity and overall well-being. Reishi is prized for its adaptogenic properties, which help the body manage stress and maintain balance.

Value-Added Products:

- **Stress-Relief Supplements:** Reishi is a popular ingredient in stress-relief supplements, available in various forms, including capsules, powders, and tinctures. These products are designed to support the body's stress response, improve sleep quality, and promote a sense of calm. Reishi's calming effects make it a key component in formulations aimed at reducing anxiety and supporting mental health.
- **Calming Teas:** Reishi mushroom tea is a popular choice for those looking to relax naturally. These teas are often blended with other calming herbs like chamomile and valerian root, creating a soothing drink that promotes relaxation and restful sleep.
- **Skincare Products:** The beauty industry has also embraced Reishi, incorporating it into skincare products such as serums, creams, and masks. Reishi's antioxidant properties help protect the skin from environmental damage, reduce inflammation, and promote a youthful complexion.

Hericium (Lion's Mane): The Brain Booster

Hericium erinaceus, known as *Lion's Mane*, is renowned for its cognitive-enhancing properties. This unique mushroom, with its flowing tendrils, has been used traditionally to support brain health, improve memory, and enhance focus.

Value-Added Products:

- **Cognitive Supplements:** Lion's Mane is a star ingredient in the brain boosting supplements market, where it is used in supplements aimed at boosting cognitive function. These products are popular among students, professionals, and anyone looking to enhance mental clarity and focus.

- **Brain-Boosting Beverages:** Lion's Mane is also featured in functional beverages, such as coffee and tea blends, that promote mental sharpness. These drinks offer a natural alternative to traditional stimulants, providing cognitive support without the crash associated with caffeine.
- **Memory Support Capsules:** With its potential to stimulate nerve growth factor (NGF) production, Lion's Mane is included in supplements specifically designed to support memory and cognitive health. These products are increasingly popular among older adults seeking to maintain mental acuity as they age.

Turkey Tail: The Immune Supporter

Trametes versicolor, commonly known as Turkey Tail, is a colorful mushroom that has been used in traditional medicine for its immune-boosting properties. Turkey Tail is rich in polysaccharopeptides, which are believed to enhance immune function.

Value-Added Products:

- **Immune-Boosting Supplements:** Turkey Tail is a staple in immune support supplements, available in capsules, powders, and extracts. These products are designed to enhance the body's natural defenses, making them particularly popular during cold and flu season. Turkey Tail supplements are often combined with other immune-boosting mushrooms like Reishi and Maitake to create comprehensive immune support formulas.
- **Wellness Teas:** Turkey Tail tea is gaining popularity as a daily wellness drink, offering immune support in a soothing and enjoyable form. These teas are often marketed as part of a daily health regimen, providing a simple way to incorporate immune-boosting benefits into one's routine.
- **Probiotic Supplements:** The gut health benefits of Turkey Tail have led to its inclusion in probiotic supplements. Turkey Tail's prebiotic properties help nourish beneficial gut bacteria, supporting a healthy digestive system and a strong immune response.

Combining Medicinal Mushrooms: The Power of Synergy

One of the most exciting trends in the value-added product market is the combination of multiple medicinal mushrooms into a single product. These synergistic blends are designed to amplify the benefits of each mushroom, creating powerful formulations that support overall health and wellness.

Multi-Mushroom Supplements: These supplements combine the benefits of Cordyceps, Reishi, Lion's Mane, Turkey Tail, and other medicinal mushrooms into one convenient product. By harnessing the unique properties of each mushroom, these supplements offer comprehensive support for energy, immunity, stress management, and cognitive function. Multi-mushroom supplements are available in various forms, including capsules, powders, and liquid extracts, catering to different consumer preferences.

Superfood Powders: Medicinal mushrooms are also a popular addition to superfood powders, which are often used in smoothies and other beverages. These powders combine the health benefits of mushrooms with other superfoods like spirulina, maca, and acai, creating nutrient-dense blends that support overall wellness. Superfood powders are a convenient way to incorporate a wide range of health-boosting ingredients into one's diet.

Functional Foods: Beyond supplements, medicinal mushrooms are being incorporated into functional foods, such as protein bars, chocolates, and even baked goods. These products offer a delicious way to enjoy the health benefits of medicinal mushrooms, making it easier than ever to integrate these powerful fungi into daily life.

Medicinal Mushrooms in Skincare: Beauty and Wellness Combined

The beauty industry is increasingly recognizing the potential of medicinal mushrooms, with a growing number of skincare products featuring these fungi as key ingredients. The antioxidant, anti-inflammatory, and hydrating properties of medicinal mushrooms make them ideal for promoting healthy, radiant skin.

Reishi-Infused Skincare: Reishi's anti-aging properties have made it a popular ingredient in skincare products aimed at reducing the appearance of fine lines and wrinkles. Reishi-infused creams, serums, and masks are designed to hydrate the skin, improve elasticity, and protect against environmental damage.

Chaga and Tremella: Chaga and Tremella (Snow Mushroom) are also making waves in the skincare industry. Chaga is known for its antioxidant properties, which help protect the skin from free radicals and promote a youthful complexion. Tremella, on the other hand, is celebrated for its ability to retain moisture, making it a powerful hydrating ingredient in skincare formulations.

Anti-Inflammatory Benefits: Medicinal mushrooms like Reishi and Turkey Tail are rich in anti-inflammatory compounds, making them valuable in products designed to soothe and calm the skin. These mushrooms are often used in formulations for sensitive or irritated skin, helping to reduce redness and promote a balanced complexion.

Conclusion

Medicinal mushrooms have moved beyond their traditional roots to become central players in the modern health and wellness industry. Through innovative value-added products such as supplements, functional foods, skincare, and even plant-based meat alternatives, these powerful fungi are now more accessible than ever. The science behind Cordyceps, Ganoderma, Hericium, and Turkey Tail underscores their potential to enhance energy, support immune function, boost cognitive health, and more. As the market continues to evolve, with increasing focus on personalized health solutions and sustainable practices, the future of medicinal mushrooms is promising. These fungi are not just a passing trend; they are a sustainable, natural resource that could significantly impact global health. Whether incorporating mushroom-infused coffee into our daily routine, consuming meals enhanced with Lion's Mane, or utilizing Reishi in skincare products, it is evident that medicinal mushrooms are establishing a lasting presence. They are connecting ancient wisdom with modern health practices, showing their lasting importance and potential for the future.

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ISSN : 2583-0910
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Peer reviewed
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Article ID : 04/IX/22/0924

APPLICATION OF IMAGE PROCESSING TECHNIQUES IN MUSHROOM INDUSTRY

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Abstract

Image processing techniques can significantly take mushroom production to the next level by enhancing identification, quality control, and automation. Mushroom identification and classification could be more accurate when human expertise is implemented for developing image recognition based AI models. Postharvest management of mushrooms can be more effective with the help of image processing in sorting and postharvest quality monitoring. Image processing can improve the quality control of spawn by detecting the contamination in early stages. Additionally, image processing can facilitate the disease detection and monitoring of mushroom growth during the crop management.

Introduction

Mushrooms are nutritionally rich and contain protein, low fat, dietary fiber and vitamin D. Presently, mushroom industry is facing growing concerns of crop productivity and quality. Image processing techniques are being adopted in agriculture sector for more precision and lowering the cost on equipment. As compared to traditional agriculture practices which rely on human labor, modern image processing based machine learning techniques offers more accurate processing and execution of the tasks. Recently studies have reported application of image processing in mushroom sector such as classification of edible and poisonous mushrooms, quantification of postharvest mushroom color changes, sorting and grading of mushrooms, harvesting of mushrooms etc.

Mushroom species identification

Mushrooms are a type of fungi that can offer significant nutritional benefits and health advantages when they are edible species. However, certain mushroom species are toxic and contain poisonous substances that can cause severe illness or even death. The primary reason for consuming toxic mushrooms is the lack of awareness and required skill in differentiating between mushrooms which are edible or poisonous. Additionally, many mushrooms share similar physical characteristics, complicating accurate identification. Image processing can aid in identifying different types of mushroom species based on their physical appearance and characteristics. Image processing algorithms can analyze shape, color, and texture to differentiate between poisonous and edible mushroom species. Models trained on the basis of image dataset can segregate mushrooms into different classes or species. It can improve the accuracy and efficiency in commercial and research applications in the field of mushrooms. Preechasuk *et al.*, (2020) have reported the use of image analysis and convolutional neural network (CNN) for the classification of mushrooms into edible and poisonous. They have developed an image processing algorithm and model to identify and classify mushroom images.

Postharvest color changes in mushroom

Consumer acceptance of white button mushrooms is greatly influenced by their whiteness. Browning is a significant issue with harvested mushrooms, often linked to polyphenol oxidase (PPO) activity. This enzymatic activity is triggered by physical and mechanical damage, such as bruising during picking, harvesting, handling, and transportation. Browning not only reduces the shelf life and value of the mushrooms but also leads to market rejection, resulting in substantial losses for producers. Therefore, the color and appearance of button mushroom is crucial for determining their quality and market value. Storage studies on refrigerated storage of damaged and undamaged mushroom fruit bodies under refrigerated conditions were conducted and color changes were quantified using image processing techniques (Arjun *et al*., 2022). Color parameters such as *L* value, *b* value, *a* value, browning index etc. can be accurately determined from the RGB images of mushroom fruit bodies acquired on suitable dark background.

Sorting and grading of mushrooms

The market value of white button mushroom (*Agaricus bisporus*) is greatly influenced by various factors, such as size and condition of mushroom cap. Therefore, the postharvest processing of this mushroom has gained an international attention for the development of grading system based on physical size of the mushroom fruit bodies. Image processing can help in the mechanized inspection of mushrooms by means of detecting defects, disease and overall quality control. This helps in grading mushrooms based on size, color, and overall appearance. Wang *et al*., (2018a, b) and Lu *et al*., (2017) developed an automatic sorting system that classifies white button mushrooms (*Agaricus bisporus*) based on the diameter of their caps.

Sorting of contaminated mushroom spawn

Mushroom spawn is highly susceptible to contamination at the time of incubation and if the contamination goes unnoticed it can result in losses during the cropping stage. Therefore, it is important to detect the contamination in early stages and possibly discard the contaminated spawn before it is mistakenly used. Traditionally, on mushroom farms manual inspection is practiced for sorting of contaminated spawn. Manual sorting is laborious and has high risk of errors. In order to make the sorting process of mushroom spawn more accurate, image processing based machine learning approach is reported (Tongcham *et al*., 2020). Different classification algorithms were used in their study and algorithm with most accurate results was finally selected for mushroom spawn classification.

Mushroom harvesting

Design and development of image processing based automatic mushroom harvesting mechanism is under process. Some studies have reported such automatic harvesting systems for button mushroom grown in beds. Image processing based harvesting system suitable for bag cultivation of mushroom is also reported. However, these harvesting systems have challenges for their wide adoption due to additional factors such as cleaning and low light conditions in cropping rooms (Yin *et al*., 2022).

Detection of pests and diseases

Image processing can help to identify symptoms of fungal infections, mold etc. by analyzing images of mushrooms and their growing environments. In order to enable early intervention, images can be analysed to detect pests or insects which may affect the growth of the mushroom. Jong Kim *et* *al*., (2017) have reported a system for analysing the status of mushroom pests by using image recognition based CNN model.

Monitoring of mushroom growth

Growth of mushroom in cropping rooms can be monitored over the period of cropping cycle by making the use of image processing technique. Image processing algorithm can track the changes in size and fruit body development by capturing images at regular intervals during growth phase. Also optimal growing conditions can be better understood through analysis of images acquired from the growing environment. Researchers have reported a CNN based system to measure the size of mushroom fruit bodies, counting of mushrooms and to determine the growth rate of the mushrooms. This system is reportedly useful in increasing the effectiveness in production management (Pin Lu *et al*., 2019).

Research and Development

Through accurate and more precise analysis of phenotypic differences among mushroom strains, image processing can help in studying diverse genetic variations in mushrooms. Image processing can also be used in investigating the effect of different environmental factors and cultivation techniques on the growth and yield parameters of mushrooms.

Conclusion

Use of image processing is being explored in the field of mushrooms. Studies have reported the application of image processing for enhanced mushroom identification and classification, postharvest quality control, spawn quality, harvesting, pest and disease detection, growth monitoring etc. Its applications can significantly contribute in improving accuracy, efficiency, and overall management in mushroom production.

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ISSN : 2583-0910
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Peer reviewed
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Article ID : 04/IX/23/0924

BHUT JHOLIKA: THE HOTTEST CHILI OF THE EARTH WITH HUGE ECONOMIC ASPECT AND MEDICINAL APPLICATIONS

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Abstract

The article describes several potential application and economic aspects of capsicum Chinese Jacq. Locally known as 'Bhut Jholika' the hottest pepper of the world. The chili and its leaves have medicinal properties and is used for medicinal applications for muscle pain, anti- microbial activities and obesity treatment and also has antioxidant properties. The chili is even reported as anti-carcinogenic in nature. Although the G I tag is obtained by Nagaland but it is cultivated all over the whole North Eastern Region of India. The pepper finds its uses in several delicacies of hilly terrine. Due to its hotness and medicinal applications the economic potential of "Bhut Jholika" also known as Naga chili is huge in domestic and international markets.

Key Words: Bhut Jholika, Medicinal , pepper, Economic Prospects, North east India.

Introduction

'Bhut Jholika' or naga chili is of the family of Capsicum Solanaceae and is known as capsicum Chinese Jacq. The origin of this pepper is believed to be in sub-tropical Southern America and was introduced to the rest of the world by European explorer during 1500 AD. After the passage of several centuries the hottest chili of the world found its favorable place in the north eastern hilly terrines of India, in the states of Nagaland, Arunachal Pradesh, Mizoram, Manipur, Meghalaya, Sikkim and Tripura. In 1999 Nagaland got the GI tag for this chili which is also known as "NAGA CHILLI". It has more than 30 species and the hottest species has Scoville heat unit (SHU) as 1001304. The chili is used in different cuisines of India and across the world. It has several medicinal and pharmaceutical applications and also used in sprayers for self-defense and riot controls.

Fig 1.

TAXONOMY:

Kingdom-	*Plantae*	**Family-**	*solanaceae*
Division-	*Magnoliophyte*	**Genus-**	*capsicum*
Class-	*Magnoliopsida*	**Species-**	*Chinese Jacq*
Order-	*Solanas*	**Local name**	*Bhut Jholika*

Morphology [fig. 2]
Stem: Dark green in colour, Thin in size, not hard in texture.
Leaves: leaves have characteristic crinkle look as found in other chili species, green in colour, ovate in shape.
Flowers: The flowers grow like pendant in pair per axil, with creamy white corolla, anther are blue and filaments are purple.
Fruits: The chilies are elongated, sub-conical to conical in shape, 3-5 cm in length with an undulating surface, which on maturity changes colour from green to red.

Seed: White or light brown, wrinkled.

Fig. 2

Gastronomical Applications:
As the pepper is of high SHU. It is used in different cuisines in cold environment countries and area, which is very delicious and also good for gastro intestinal disorders and elimination of stomach worms such as hook worm, tape worm etc. In Latin American countries the chili is used as remedy for stomach ache, cure of hallucination sleep terror and other sleep disorders.

Medicinal uses:
The pepper has several medicinal uses for postpartum abdominal disorder, skin remedies, respiratory disorder, fever. It is also found to be anti-carcinogenic in nature and is used in different anti-cancer drug.

Economic Aspects:
As the pepper find itself in different types of medicinal application for curing several ailments such as pain relief, anti-oxidant, ant obesity, So, it has a very high demand in Pharmaceutical Industry in both domestic and international market.

Most of the chilies are produced in the North Eastern part of India have low SHU so due to high value of SHU the market price of Bhut Jholika is very high compared to the other verities produced in the north eastern part on India so economic prospect is robust for this pepper.

Conclusion
At the epilogue it is evident that Naga Chili or 'Bhut Jolika' one of the highest ranked vegetable or product of North East India both in pharmaceutical and economic aspects. Due to high global

demand the production and marketing of the pepper has to be considered with utmost importance to the economic prospects of the tribal population of farmers of North East India.

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Article ID : 04/IX/24/0924

NANOTECHNOLOGY: REVOLUTIONIZING SUSTAINABLE AGRICULTURE FOR A GREENER FUTURE

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Introduction

Research concerning applications of nanotechnology for agriculture has gained significant attention during the recent years (Usman *et al.,*2020). Nanotechnology is widely recognized for its immense potential in the agricultural sector, offering the ability to revolutionize it through the application of its principles. The sustainable growth of agriculture is increasingly reliant on innovative techniques like nanotechnology. This technology provides enhanced options for various agricultural practices, leading to improvements in productivity and efficiency. The excessive use of chemical pesticides and fertilizers, especially since the green revolution, has raised serious concerns about environmental sustainability and health risks. Researchers have indicated that nanotechnology-based formulations could address global challenges such as food demand and supply, crop production, environmental sustainability, food security, and climate change.

Nanotechnology for Sustainable Agriculture

Recent research has shown the promising potential of nanotechnology to improve the agriculture sector by increasing the efficiency of agricultural inputs and offering solutions to agricultural and environment problems for improving food productivity and security. Nanotechnology is contributing various nano-devices, nano-formulations and nano-ingredients to improve the agricultural practices such as nano-herbicides and pesticides for efficient herbs, pests and weed management and nano-fertilizers for proficient nutrient execution, nano-biosensors for detecting the on-site water level, moisture and nutrient content in soil (Pandey, 2018). Hence, we can say that, nano-technology would play a responsible role in agricultural sector by transforming the food demand and supply system through improving crop production with maintaining the ecological- sustainability, environmental- safety, and economic- stability.

Nanofertilizers

During the last five decades, an enormous increase in crops yield, especially that of cereals, played a significant role in meeting the world's nutritional requirements. Increase in use of chemical fertilizers is among the major contributors to boost the crop yield in this regard. Use of chemical fertilizers is, however, limited by their poor use efficiency due to the loss of fertilizer (by volatilization and leaching) that contaminates the environment and increases the cost of production. Nanotechnology is used to reduce the losses of mobile nutrients, to develop slow-release fertilizers, and to improve the accessibility of poorly-available nutrients. Nanofertilizers are nanomaterials which are either nutrients themselves (micro- or macro- nutrients) or are acting as carriers/additives (e.g. by compositing with minerals) for the nutrients. Nanofertilizers can also be developed by encapsulating nutrients inside the nanomaterials. Nanofertilizers improve crop yield and quality with higher nutrient use efficiency while reducing the cost of production and thus, contribute towards agricultural sustainability.

Sr No.	Index	Conventional fertilizers	Nanofertilizers
1.	**Loss rate**	High loss rate via drifting, leaching, run-off	Low loss of fertilizer nutrients
2.	**Controlled release**	Excess release of nutrients lead to high toxicity and soil imbalance	Rate of release and release pattern precisely controlled
3.	**Availability**	Low	High
4.	**Effective duration of release**	Used by the plant at the site and time of application; the rest is converted into an insoluble form	Effective and extended duration
5.	**The efficiency of nutrients uptake**	It is not available to roots and the efficiency of nutrients uptake is low	Enhanced uptake ratio and saves fertilizer resource

Table 2. Difference between Conventional fertilizers and Nanofertilizers

Nanoherbicides

Nanoherbicides are formulated by exploiting the nanotechnological potential for effectual delivery of chemical or biological pesticides with the help of nanosized preparations or nano-materials-based herbicide formulations. Nanomaterials or nanostructures materials-based formulations could improve the efficacy of the herbicide, enhance the solubility and reduce the toxicity in comparison with the conventional herbicides. Early weed control with the use of nanoparticle-based herbicide release systems could reduce the herbicide resistance potential, maintain the activity of the active ingredient and prolong their release over a longer period. The development of specific herbicide molecule encapsulated with nanoparticle aims at specific receptors present at the root of the targeted weed. The developed nanoparticle enters the root system of the weed and gets translocated to perform its action which in turn inhibits the glycolysis of the plant root system. The targeted action creates starvation of the plant and thus kills it. A glyphosate-resistant crop was reported to be made susceptible to glyphosate upon addition of a nanotechnology-based surfactant on to a soybean micelle. Nanoparticles can act as good carrier and also can form nano formulation when added with herbicides. These nano formulations assist in overcoming the main drawback of herbicide industry such as evolution of herbicide resistant plants.

Nanopesticides

Pesticides play an important role in defending of biological disasters, ensuring the crop productivity and promoting the sustained steady growth of agricultural production. However, indiscriminate pesticide usage also brings a serious threat to the environment and human health. The annual input amounts of pesticides have reached 4.6 million tons worldwide, 90% of which run off into the environment, residue in agricultural products and redistribute in ecological cycle during application. Most of the pesticide active ingredients (AIs) are water-insoluble organic compounds, which need to be added with carrier, solvent, emulsifier, dispersant and other auxiliary ingredients, and processed into a suitable formulation in order to facilitate the spray application in field. Nano-based smart formulation could release their AIs in responding to environmental triggers and biological demands more precisely through targeted delivery or controlled release mechanisms. The size-down of pesticide particles benefit to significantly improve their water-dispersion, targeting coverage and insecticidal activity due to smaller particle size and higher surface area. Developing new advanced nano-based formulations that remain stable and active in the spray condition (sun, heat, rain), penetrate and delivery to the target, prolong the effective duration, and reduce the run-off in environment, is one of the hotspots in the field of nano-technical agriculture applications.

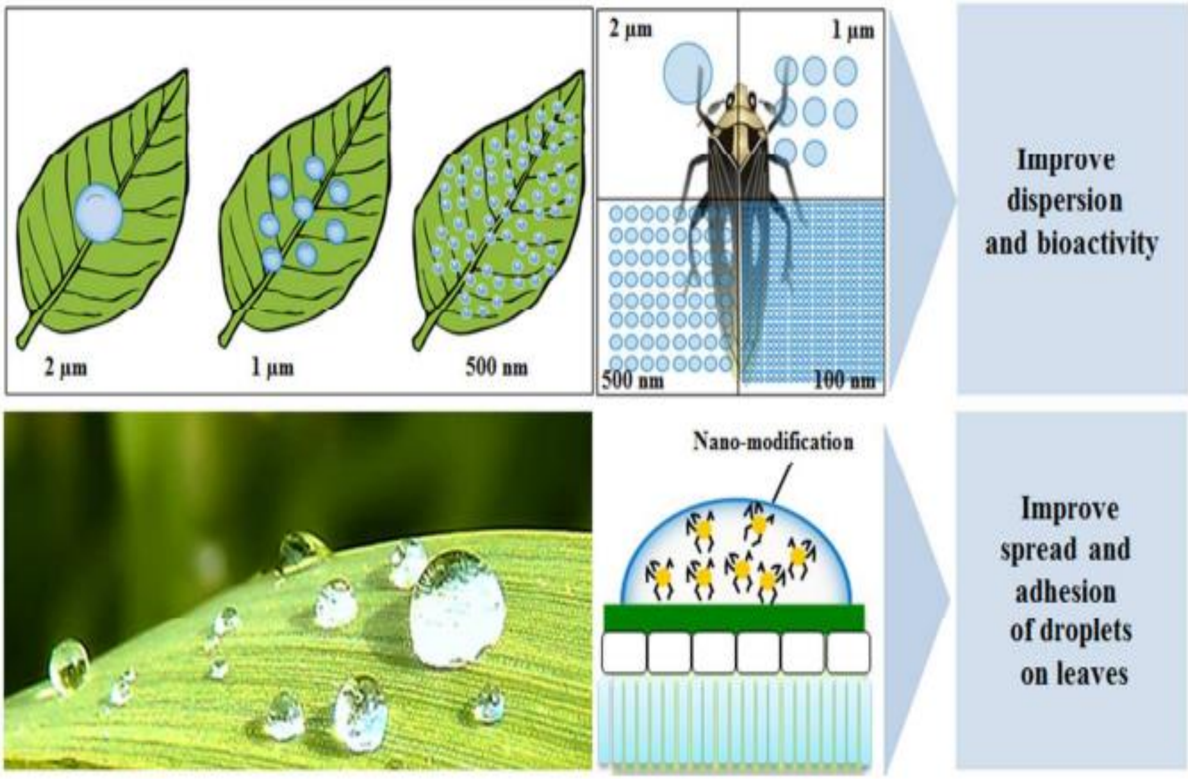

Fig 1. Size-down of pesticides increase bioavailability and efficiency

Mechanism of Nanoparticle uptake by plants

In the soil, the NPs undergo a series of bio/geo transformations, which determine the bioavailability and toxicity of NPs. The NPs translocate to aerial portions after interacting with plant roots and accumulate in cellular or subcellular organelles. The NP's size is directly connected to the absorption of the NPs because it is a crucial parameter that enables its entrance through cell wall pores or plant stomata. Besides, size determines their subsequent transport processes into cells (i.e., plasmodesmata) or organelles of plant cells, affecting their accumulation, toxicity, and kinetics of transport into plant cells. The surface area, agglomeration, and reactivity on the cell surface or within plant structures are correlated with the NP shape. The small NPs (diameters range from 3 to 5 nm) are reported to penetrate plant roots along with osmotic pressure, capillary forces, or passing directly through the root epidermal cells. The epidermal cells of the root cell wall are semipermeable containing small pores and restrict the large NPs. The NPs applied by the leaves can enter the leaves through the stomata or cuticles. The cuticle acts as a primary leaf barrier, restricting the entry of NPs to a size of <5 nm. The NPs > 10 nm enter through stomata, and their cellular transport is occurring through apoplastic and symplastic routes into the vascular system of the plant. The transfer of NPs (between 10 and 50 nm) is favored through the adjacent cell's cytoplasm (symplastic route).

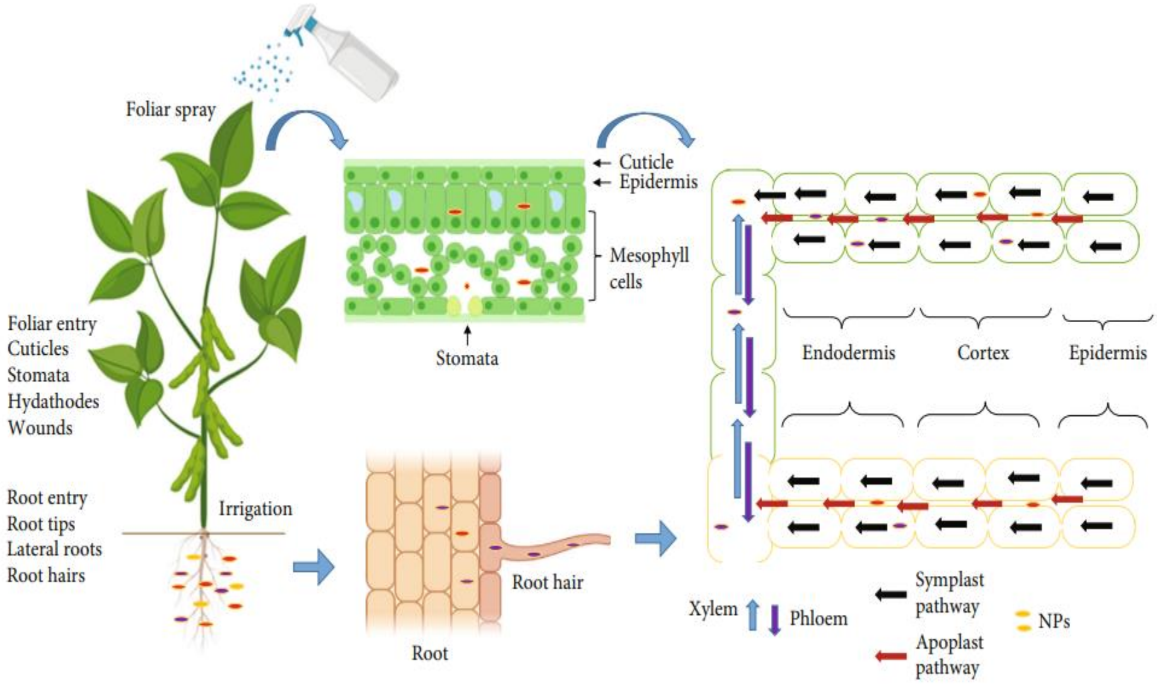

Fig 2. Schematic presentation of nanoparticle uptake through different routes and their translocation pathways in different plants' parts.

Conclusion

Nanotechnology is an emerging tool to improve productivity of crop and has capability to coup-up from present agricultural issues. Its use in agriculture holds the potential to transform agricultural production by enabling more efficient management and conservation of resources essential for plant growth. Use of nanotechnology in agriculture also aims to make plants use water, pesticides and fertilizers more efficiently, to reduce pollution and to make agriculture more environmental friendly. Nanotechnology has a potential to reduce biotic and abiotic stress in plants and is an effective agent for soil remediation.

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ISSN : 2583-0910
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Article ID : 04/IX/25/0924

NEUROENDOCRINE CONTROL OF REPRODUCTION IN CULTURED FISH AND ITS APPLICATION FOR INDUCED BREEDING

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In fish, reproductive process is controlled by neuroendocrine reproductive axis (brain-pituitary-gonad-liver, BPGL). There are different elements of reproductive axis within BPGL axis such as kisspeptin (Kiss), gonadotropin-releasing hormone (GnRH), gonadotropin (GtH): follicle stimulating hormone (FSH) and luteinizing hormone (LH), and sex steroids. Primarily, GnRH produced in the brain regulates the synthesis of pituitary gonadotropins to control the synthesis and secretion of FSH and LH. FSH plays an important role in the early stages of gametogenesis particularly during vitellogenesis in females and early stages of spermatogenesis in males. Additionally, FSH is involved in the stimulation of production of vitellogenin protein in the liver through estradiol production by somatic cells surrounding oocyte. Estradiol produced from oocyte somatic cells stimulate vitellogenin production in the liver and this vitellogenin is transferred and stored in the occyte as energy molecule for developing embryo and early larvae. LH is involved in the final stages of gametogenesis in the males and females. Specifically in females during the final stages of final oocyte maturation, ovulation and spawning. In males, during spermiogenesis and spermiation. Both FSH and LH act through their cognate receptors expressed in the somatic cells surrounding the germ cells in the gonads. In females, theca and granulosa cells are involved in the production of sex steroids, mainly testosterone and estradiol during the vitellogenic phase and maturation inducing hormone, 17α,20β-dihydroxyprogesterone during the final oocyte maturation phase. Similarly, in males sertoli and leydig cells are involved in the production of sex steroids mainly testosterone and 11-ketotestosterone during early spermatogenesis and spermiogeesis and 17α,20β-dihydroxyprogesterone during spermiation till spawning. Additionally, sex steroids feedback to the pituitary and brain to control the release of brain GnRH and pituitary GtH. In addition to this basic elements, there are number of other intermediate hormones like insulin-like growth factors which are also involved in the gametogenesis. This pathway is widely conserved in teleost reproduction.

In cultured fishes, the elements of this reproductive pathway are inhibited due to captive induced stress and limited space in the aquaculture systems. For example, number of studies have demonstrated that genes encoding *gnrh* and *gth* are expressed less in cultured fish compared to wild fish. The reason for the same has been attributed to captive induced stress and limited swimming in the captivity. Similarly, measurement of GnRH and GtH protein level in the brain and pituitary extract including peripheral serum have indicated lower level in the cultured fish compared to captive maintained fish. Measurement of circulating sex steroids levels, testosterone, 11-ketotestosterone, estradiol-17β and MIH have also indicated lower level of this steroid hormones compared to cultured fish. This information clearly indicate that captive induced stress in cultured fish result in lower rate of hormone synthesis and secretion. In recent years, molecular studies have clearly indicate that there are number of gene elements resulting in lower expression of these hormones.

In light of the above, several hormones are used for induced breeding in finfish and shellfish. In the past, mammalian based hormones were widely used for controlling reproduction in captivity. In this group, human chorionic gonadotropin (HCG), mammalian GnRH and sex steroids are administered to fish intramuscularly and intraperitoneally. Presently, fish based semi-purified and purified gonadotopins, fish GnRH analogues like WOVA-FH, Ovaprim and Ovatide are widely used for induced breeding. These hormones can be administered using syringes and slow releasing medium like cocoa butter and osmotic pumps. Additionally, many new inducing agents have been suggested to be potential inducing agents like kisspeptins, neurokinin B and dynorphin. The new inducing agents need to be used in the other cultured fish to promote its use in India. Our institute is also giving training to the farmers to undertake mass scale seed production in ponds and tanks for different ornamental and food fish. Farmers and entrepreneurs can use this opportunity to get trained.

Several molecular information on GnRH and GtH in cultured fish has resulted in development of recombinant hormones for its application in fish. The molecular information can be primarily accessed through Genebank database of NCBI, USA and other data banks of different countries. Using the recent genome editing techniques like TALEN and CRISPR based system can be effectively used to target specific genes to understand their function and produce superior quality fish. In light of the above, model fishes from India like ornamental zebrafish and food fish tilapia can be exploited to understand the neuroendocrine control of reproduction in cultured finfish and shellfish. Several Indian cultured fishes have been recently sequenced and this information can be effectively used to control reproduction in captivity. Multiinstitute collaboration will further help to obtain detailed molecular and genetic information from cultured fish and can be used to control growth and reproduction in captivity as most cultured fishes exhibit slower growth and poor reproductive ability.

ISSN : 2583-0910
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Article ID : 04/IX/26/0924

THE VILLAGE: THE DREAM

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Abstract
"The Village: The Dream" is a Deep & Peak study of how a community and individuals respond under pressure and fear while living. I'm not even sure I would describe it as a short article. But don't get me wrong, there are some real moments in the article. A dream village is a hypothetical or conceptual village that embodies ideal characteristics, amenities, and qualities that make it an desirable place to live with Harmony with nature, Close-knit community, Holistic well-being, Lifelong learning, Inclusivity and diversity, Vibrant culture, Economic opportunities, Safety and security, Accessibility and connectivity, Resilience and adaptability.

Keywords: Village, Challenges, Strategies, Schemes, Rural Development

Concept
Every village is unique, so it's essential to Conduct a thorough needs assessment, Involve the community in planning and decision-making, Prioritize initiatives based on local needs and resources, Monitor progress and adapt strategies as needed.

Village problems can vary depending on the location, size, and resources of the village. Here are some common challenges faced by many villages,

- Limited access to basic amenities like healthcare, education, and sanitation
- Poor infrastructure, including roads, electricity, and water supply
- Economic struggles, such as poverty, unemployment, and limited job opportunities
- Environmental concerns, like pollution, deforestation, and climate change
- Social issues, including gender inequality, caste discrimination, and social exclusion
- Limited access to technology, internet, and digital services
- Brain drain, as young people leave villages for better opportunities in cities
- Natural disaster risks, such as floods, droughts, and landslides
- Limited access to markets, making it hard for villagers to sell their products
- Governance and administrative challenges, including corruption and lack of transparency etc.

Improving a village requires a multi-faceted approach that addresses its unique challenges. Some strategies mentioned below are applied for development of village.

1) Infrastructure development: Invest in roads, bridges, and public transportation to enhance connectivity.
2) Access to basic amenities: Ensure availability of clean water, sanitation, healthcare, and education.
3) Economic empowerment: Support local businesses, entrepreneurship, and skill development to reduce unemployment.

4) Digital inclusion: Introduce internet, digital literacy programs, and online services to bridge the technology gap.
5) Environmental conservation: Implement sustainable practices, renewable energy, and waste management to protect natural resources.
6) Social welfare programs: Address social issues like gender equality, caste discrimination, and social exclusion through awareness and support initiatives.
7) Community engagement: Foster participatory governance, encouraging villagers to contribute to decision-making processes.
8) Capacity building: Train local leaders, youth, and community members in leadership, management, and technical skills.
9) Partnerships and collaborations: Engage with NGOs, government agencies, and private organizations to leverage resources and expertise.
10) Innovative solutions: Encourage innovative approaches, like rural tourism, agri-tech, and social entrepreneurship, to address village-specific challenges.

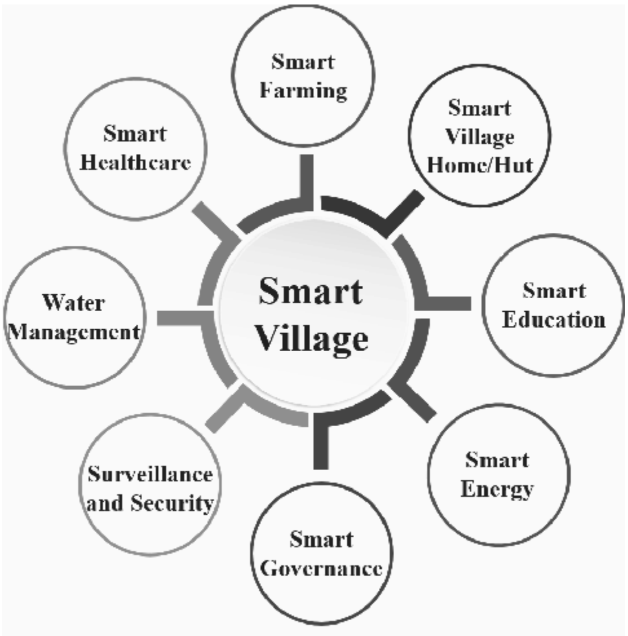

Fig. 1 Smart Village

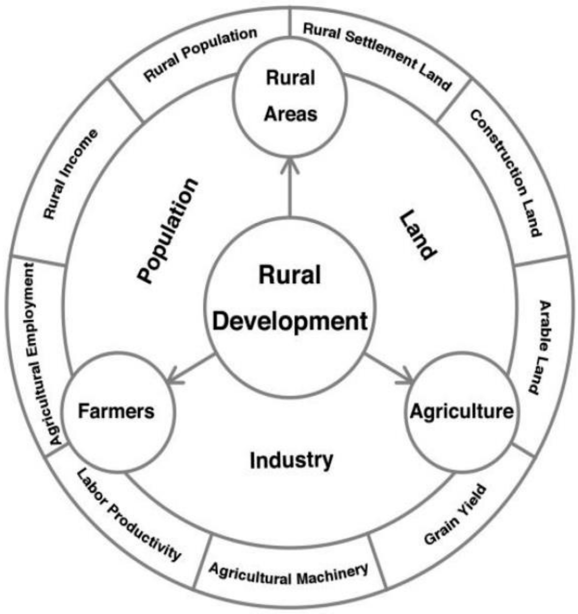

Fig. 2 Rural Development

Developed/Smart villages often share certain characteristics that contribute to their success and sustainability. Some common features of developed villages are Strong community engagement, Good governance, Transparent, Access to basic amenities, Availability of clean water, sanitation, healthcare, education, and electricity, Economic opportunities, Sustainable infrastructure, Environmental conservation, Social cohesion, Innovative approaches, Partnerships and collaborations, Continuous learning, Disaster resilience, Inclusive and equitable, Cultural preservation, Waste management, Renewable energy etc.

Villages and education are closely linked, as education can greatly impact the development and progress of rural communities with Access to education, Literacy rates, Education infrastructure, Teacher availability, Curriculum relevance, Vocational training, Digital literacy, Community involvement, Cultural preservation and Empowerment etc.

Initiatives to improve education in villages includes, Rural school development programs, Teacher training and support, Digital education platforms, Vocational training and skill development, Community-led education initiatives, Scholarships and financial support, Innovative education models, Partnerships with NGOs and organizations etc.

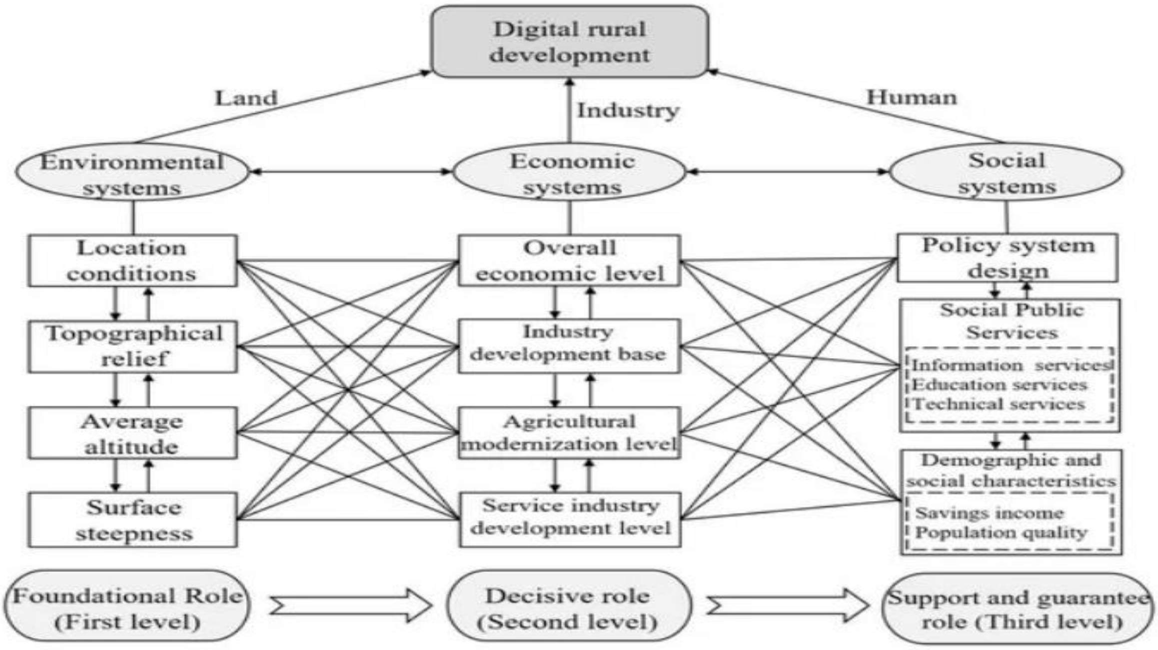

Fig. 3 Digital Rural Development

India has made significant progress in developing its villages, with various initiatives and programs aimed at improving rural infrastructure, amenities, and quality of life.

Hiware Bazar (Maharashtra): Known for its water conservation efforts, Hiware Bazar has become a model for sustainable development.

Mawlynnong (Meghalaya): This village is famous for its cleanliness, organic farming, and women's empowerment initiatives.

Dhundi (Gujarat): A model village for renewable energy, Dhundi uses solar and wind power to meet its energy needs.

Punsari (Gujarat): This village boasts of modern amenities like a robotic school, e-library, and digital healthcare services.

Kedia (Gujarat): A village with 100% literacy rate, Kedia has also implemented innovative agricultural practices.

Ralegan Siddhi (Maharashtra): A model for sustainable development, this village has implemented water harvesting, renewable energy, and waste management initiatives.

Thamna (Gujarat): This village has made significant progress in education, healthcare, and sanitation, becoming a model for rural development.

Mundra (Gujarat): A coastal village with modern amenities like a desalination plant, solar power, and a robust education system.

Pochampalli (Telangana): Known for its handloom weaving industry, Pochampalli has also implemented initiatives for women's empowerment and education.

Shani Shingnapur (Maharashtra): A village famous for its trust-based banking system and community-led development initiatives. etc.

Some government and non-government schemes in villages in **India** included in following Table 1

Government schemes	Non- Government schemes
1. Pradhan Mantri Gram Sadak Yojana (PMGSY): Rural road development 2. Pradhan Mantri Awas Yojana (PMAY): Affordable housing 3. Swachh Bharat Abhiyan (SBA): Sanitation and cleanliness 4. National Rural Employment Guarantee Act (NREGA): Employment guarantee 5. Pradhan Mantri Gramin Awaas Yojana (PMGAY): Rural housing 6. Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY): Rural electrification 7. National Rural Health Mission (NRHM): Healthcare 8. Sarva Shiksha Abhiyan (SSA): Education 9. Pradhan Mantri Ujjwala Yojana (PMUY): LPG connections 10. National Social Assistance Programme (NSAP): Social welfare etc.	1. Digital Village Program: Digital literacy and internet access 2. Village Adoption Program: Holistic village development 3. Model Village Program: Sustainable development 4. Rural Entrepreneurship Development Program: Entrepreneurship support 5. Village Health Worker Program: Community health workers 6. Rural Education and Literacy Program: Education and literacy 7. Village Infrastructure Development Program: Infrastructure development 8. Sustainable Agriculture Program: Sustainable farming practices 9. Rural Women Empowerment Program: Women's empowerment 10. Village Tourism Development Program: Rural tourism promotion etc.

Innovative Ideas for Rural Development in India

Utilization of Local Resources: If there are water sources nearby, such as rivers and tanks, plans must be developed to access them in the summer by closing holes in the tanks, building new reservoirs, bunds, and canals while bolstering the ones that already exist to prevent water loss. In a similar vein, any iron, coal, or granite mines should be explored in order to offer work for the local community.

Establishment of Rural Industries: All the village industries come under the following broad categories:

Agro Based Industries: Sugar industries, Jaggery, Oil processing from oil seeds, Pickles, Fruit juice, Spices, Dairy products etc.

Forest Based Industries: Wood products, Bamboo products, Honey, Coir industry, making eating plates from leaves.

Mineral based industry: Stone crushing, Cement industries, red oxide making, wall coating powders etc.

Textile Industry: Spinning, Weaving, Colouring and Bleaching.

Engineering and Services: Tractors and Pump set repairs etc. Small and medium sized industries to produce agricultural machinery, equipment for usage in rural areas etc.

Handicrafts: These include producing regionally unique wooden or bamboo handicrafts, traditional ornamental items, toys, and all other types of handicrafts.

Services: There are a wide range of services including mobile repair, agriculture machinery servicing, etc which are being undertaken under this category.

Startups: They are entrepreneurial initiatives, which are recently established enterprises that try to address a need, demand, or problem in the market by creating a workable business model based on goods, services, procedures, or platforms. As an illustration, consider the following topics: agriculture, supply chains, trading in agricultural products, processing agricultural products, fisheries - both culture and trade, rural microfinance, rural health, rural primary health care, and rural education, among others.

Computer & Internet Services: Providing Computer Training and Repairing Services, Internet based business-like E-Commerce, Rail & Bus Ticket booking, Digital Marketing Agency – Examples: Social Media Marketing, Email Marketing etc.

Encourage Rural Entrepreneurship: These are some possible kinds for them: Individual entrepreneurship is essentially one person owning the business. Group entrepreneurship, or "group entrepreneurship," mostly refers to partnerships, private limited companies, and public limited companies. Entrepreneurship in Cluster Formation, or c), includes networking between NGOs, VOs, CBOs, SHGs, and other similar organisations. These also include the formal and informal grouping of people based on things like caste, occupation, money, etc. Cooperative entrepreneurship is an autonomous group of people who have voluntarily come together for a shared goal.

Conclusion

India's economic progress, especially in the rural sector, depends heavily on rural development. It contributes to the growth of agriculture by lowering hidden unemployment, underemployment, unemployment, poverty, migration, and economic inequity. It also helps to provide employment possibilities in rural regions with modest capital requirements. This article is based on the current conditions in villages as already known every village is having unique identity and overcoming problems faced by in the village is necessary from development point of view.

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ISSN : 2583-0910
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Article ID : 04/IX/27/0924

FROM WASTE TO WONDER: THE ROLE OF MUSHROOMS IN THE CIRCULAR ECONOMY

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Abstract
Mushrooms play a transformative role in the circular economy, embodying sustainability by recycling organic waste, supporting sustainable agriculture, and driving innovative product development. This article explores how mushrooms, as natural recyclers, break down organic matter into valuable nutrients, enriching soils and closing agricultural loops. It highlights the integration of mushrooms into sustainable farming practices and their potential in environmental restoration through myco-remediation and myco-filtration. The article also delves into emerging mushroom-based products, such as biodegradable packaging, mushroom leather, and plant-based proteins, which offer eco-friendly alternatives to conventional materials. While challenges exist in scaling these innovations, the future of mushrooms in the circular economy is promising, with the potential to significantly contribute to a more sustainable and regenerative global economy.

Key words: Circular economy, mushroom, sustainability, myco-remediation, biodegradable products

Introduction

The circular economy is a transformative model that emphasizes resource efficiency, sustainability, and waste reduction. Unlike the traditional linear economy, which follows a "take-make-dispose" approach, the circular economy seeks to keep products, materials, and resources in use for as long as possible. Within this context, mushrooms play a unique and increasingly significant role. As versatile organisms that thrive on organic waste, mushrooms exemplify the principles of the circular economy. This article explores the various ways mushrooms contribute to a circular economy, from waste recycling and sustainable agriculture to innovative products and environmental restoration.

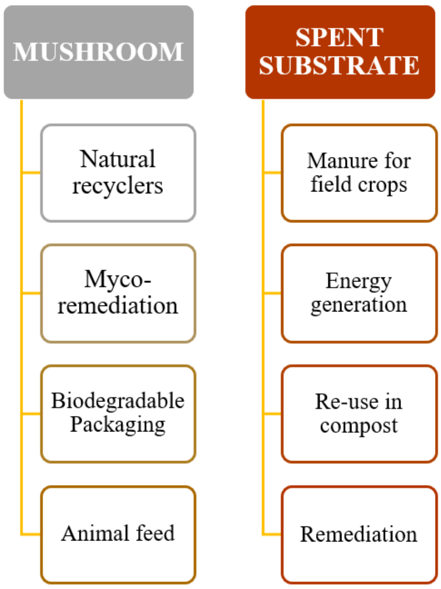

Figure 1. Various uses of mushroom and spent mushroom substrate in circular economy

Mushrooms as natural recyclers

One of the most critical functions of mushrooms in the circular economy is their ability to act as natural recyclers. Fungi, particularly mushrooms, are decomposers that break down organic matter, converting it into nutrients that can be reused by plants and other organisms. This decomposition process is vital for nutrient cycling in ecosystems and helps maintain soil health.

In an agricultural context, mushroom farming often utilizes agricultural by-products such as straw, sawdust, and coffee grounds as substrates. These materials, which might otherwise be discarded as waste, are repurposed to cultivate mushrooms. After harvesting, the spent substrate, enriched with fungal biomass and nutrients, can be used as a high-quality organic fertilizer or soil amendment, further closing the loop in agricultural production. This practice not only reduces waste but also enhances soil fertility, promoting sustainable farming practices.

Mushroom cultivation and sustainable agriculture

Mushroom cultivation is inherently aligned with the principles of the circular economy due to its low environmental impact and efficient use of resources. Unlike many conventional crops, mushrooms do not require large amounts of land, water, or chemical inputs. They can be grown in controlled environments, using minimal space and resources, making them an ideal crop for sustainable agriculture.

In addition, mushrooms contribute to sustainable agriculture through their role in myco-remediation, a process where fungi are used to degrade or remove environmental contaminants. Certain species of mushrooms have the ability to break down complex pollutants, such as pesticides, heavy metals, and petroleum products, turning them into less harmful substances. This capability makes mushrooms valuable tools for cleaning up contaminated soils and restoring degraded land, further supporting the goals of a circular economy.

Innovative mushroom-based products

Beyond their role in waste recycling and sustainable agriculture, mushrooms are at the forefront of innovative, sustainable product development. Advances in biotechnology and material science have led to the creation of a wide range of mushroom-based products that align with circular economy principles.

One of the most notable innovations is mushroom-based packaging, which offers a sustainable alternative to conventional plastic packaging. Varios companies have developed biodegradable packaging materials made from mycelium, the root-like structure of fungi. These materials are not only environmentally friendly but also offer similar performance characteristics to traditional plastics. After use, mycelium-based packaging can be composted, returning nutrients to the soil rather than contributing to landfill waste. Another emerging area is the use of mushrooms in textiles and fashion. Mushroom leather, made from mycelium, is a sustainable alternative to animal leather. It is produced with significantly less water and energy and does not involve the harmful chemicals typically used in tanning processes. Mushroom leather is also biodegradable, reducing the environmental impact at the end of its life cycle.

Additionally, mushrooms are being explored as a source of plant-based proteins in the food industry. Mycoprotein, a protein derived from fungi, is used as a meat substitute in various products. It offers a sustainable alternative to animal-based proteins, requiring fewer resources and producing lower greenhouse gas emissions. As consumer demand for sustainable and ethical food options grows, mushroom-based proteins are likely to play an increasingly important role in the circular food economy.

The role of mushrooms in environmental restoration

Mushrooms also have a significant role in environmental restoration, another key component of the circular economy. Their ability to decompose organic matter and break down pollutants makes them valuable allies in efforts to restore ecosystems and manage waste sustainably.

One of the most promising applications of mushrooms in environmental restoration is myco-filtration, where fungi are used to filter and purify water. Mycelium can capture and break down harmful pathogens, chemicals, and heavy metals, making it an effective tool for treating wastewater and improving water quality. This process not only cleans water but also prevents pollutants from entering and damaging ecosystems. In addition to water purification, mushrooms are used in myco-forestry, where they help to rehabilitate and sustain forest ecosystems. Fungi form symbiotic relationships with trees, known as mycorrhizal associations, which enhance the trees' nutrient uptake and improve their resilience to environmental stressors. By supporting tree health, mushrooms contribute to the restoration and preservation of forest ecosystems, which are vital for carbon sequestration and biodiversity.

Challenges and Future Prospects

While mushrooms offer numerous benefits to the circular economy, there are also challenges that need to be addressed to fully realize their potential. One of the primary challenges is scaling up mushroom-based solutions to meet global demand. While mushroom cultivation is relatively simple, producing mushroom-based products, such as packaging and textiles, at an industrial scale requires significant investment in research, development, and infrastructure.

Another challenge is consumer acceptance and market penetration. Although there is growing interest in sustainable products, widespread adoption of mushroom-based alternatives will depend on consumer education, affordability, and availability. Overcoming these barriers will require collaboration between industry, government, and consumers to create supportive policies and market conditions. Despite these challenges, the future prospects for mushrooms in the circular economy are promising. Continued advancements in mycology, biotechnology, and material science are likely to unlock new applications for mushrooms, further enhancing their role in sustainable development. As the global economy shifts towards more sustainable practices, mushrooms are poised to play a crucial role in creating a more resilient and regenerative system.

Conclusion

Mushrooms are more than just a nutritious food source; they are key players in the circular economy. Their ability to recycle organic waste, contribute to sustainable agriculture, and inspire innovative products makes them invaluable in the quest for a more sustainable and circular future. By embracing the potential of mushrooms, we can not only reduce waste and conserve resources but also create new opportunities for economic growth and environmental restoration. As the circular economy continues to gain momentum, mushrooms will undoubtedly remain at the forefront of this transformative movement.

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/28/0924

GREEN GOLD: UNLEASHING NUTRIENT CYCLING THROUGH AGROFORESTRY

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ABSTRACT

Nutrient availability in the soil is essential to the food cycle, influencing the growth and development of all living organisms on Earth. The presence of inorganic nutrients in the soil determines the nutritional status of plants and their ability to absorb these nutrients. Agroforestry systems (AFS), which integrate the cultivation of crops or the use of animals with tree planting on arable land, offer an alternative agricultural practice that enhances soil health and productivity. Litter addition, decomposition and nutrient release, biological nitrogen fixation, nutrient pumping, and erosion control are all critical activities performed by agroforestry systems to improve soil nutrient status and ensure sustainable agricultural output.

Key words: Agroforestry, Nutrient cycling, decomposition, soil health, Productivity.

INTRODUCTION

Agroforestry is an integrated land management system that involves cultivating agricultural crops, forest tree species, and/or raising animals either simultaneously or sequentially on the same plot of land. By employing appropriate management practices, this approach leads to an overall increase in production under specific climatic and soil conditions, while also improving the socioeconomic status of local communities. In India, agroforestry covers 25.32 million hectares, representing 8.2% of the country's total geographical area. This includes 20.0 million hectares in cultivated fields, with 7.0 million hectares in irrigated areas and 13.0 million hectares in rainfed regions, along with 5.32 million hectares in other areas such as shifting cultivation (2.28 million hectares), home gardens, and soil rehabilitation on problematic lands (2.93 million hectares).

Nutrient recycling in natural ecosystems provides numerous ecosystem services that are vital for human well-being. Agroforestry systems, with their inclusion of woody perennials and positive soil impacts, are more efficient at nutrient cycling compared to monoculture systems.

Furthermore, woody perennials have bigger and deeper root systems, which allow them to collect and recycle more nutrients than herbaceous plants. Their litter contribution to the soil surface is likely larger than that of herbaceous plants. Furthermore, agroforestry has several potential benefits, including increased overall productivity, improved soil fertility, soil conservation, nutrient cycling, microclimate enhancement, carbon sequestration, bio-drainage, bio-energy, and biofuel production.

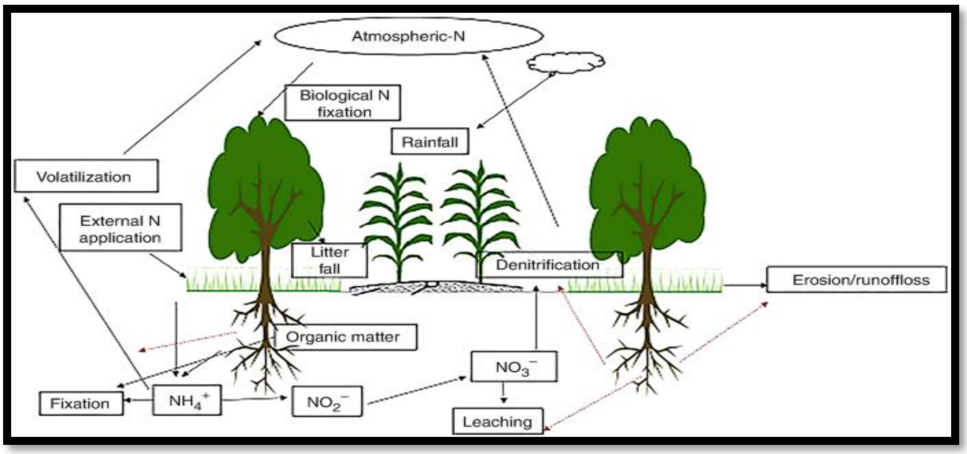

Fig 1: Nutrient cycling in Agroforestry

Nutrient cycling in Agroforestry

The cycle consists of gain inputs, loss outputs, and the internal turnover or transfer within the system. Forest ecosystems are closed and efficient in nutrient cycling, characterized by high turnover rates with minimal losses. In contrast, common agricultural systems are open or "leaky," with minimal turnover but significant losses and inputs. Nutrient cycling in agroforestry systems falls between these extremes, where plants retain more nutrients within the system compared to agricultural systems before they are lost. The key difference between agroforestry and other land use systems lies in the transfer or turnover of nutrients within the system's components, and the ability to manage these components to enhance turnover rates without reducing overall productivity. Trees, with their deep roots, can access nutrients from soil depths unreachable by crop roots.

Litter

Litter in agroforestry systems enhances nitrogen cycling and soil fertility by providing essential nutrients necessary for plant growth (Zheng, 2006). The decomposition of litter which includes leaves, twigs, bark, reproductive materials, amorphous substances from trees, and agricultural residues, returns organic matter and nutrients from plant parts to the soil surface, thereby boosting soil fertility. The amount of litter generated in these systems is influenced by various factors, such as the type of tree and crop species, as well as climatic, soil, topographic, and biotic conditions, all of which affect plant growth and phenology (Rawat *et al.,* 2009). Litter fall is typically higher during the summer and spring, contributing to 25% of total litter production, while autumn sees the lowest litterfall. This increase in litter during the warmer months is due to higher wind velocities that promote leaf abscission (Munishamappa *et al.,* 2012; Singh *et al.,* 2011).

Nitrogen fixation by trees:

Nitrogen-fixing trees (NFTs) may transform atmospheric nitrogen into useful chemicals such as ammonia. This unique feature enables them to use air nitrogen for their own purposes and deposit it to the soil. Leguminous plants, such as lucerne and clover (perennials) and beans, peanuts and soybeans (annuals), are noted for their excellent nitrogen-fixing ability. Examples of nitrogen-fixing trees include: *Acacia mearnsii, Casuarina equisetifolia, Erythrina poeppigian, Faidherbia albida, Gliricidia sepium* (Table: 1). these trees assist to maintain nitrogen levels in the soil through bacterial activity. Through the creation of nodule roots, they extract nitrogen from the atmosphere and store it. Nitrogen-fixing plants may significantly enhance nitrogen inputs into agroforestry systems.

Symbiotic fixation occurs through associations of plant roots with nitrogen fixing bacteria. The symbioses are:

- ✓ Between many leguminous species and rhizobium or bradyrhizobium, forming nodules on roots;
- ✓ Between a small number of non-leguminous genera and Frankia

Table1: Important N_2 fixing plant species

Plant	Scientificname	Family	Nitrogenfixed (kg N/ha/yr)
Black wattle	*Acacia mearnsii* De Wild.	Mimosoideae	200
Beef wood	*Casuarina equisetifolia* L.	Casuarinaceae	60-110
Erythrina	*Erythrina poeppigiana (Walp.) Cook*	Papilionoideae	60
Apple-ring Acacia,	*Faidherbia albida* (Delile) A.Chev.	Mimosoideae	20
Gliricidia	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Fabaceae	13
Inga	*Inga jinicuil*	Mimosoideae	35-40
Subabool	*Leucaena leucocephala* (Lam.)de Wit.	Mimosoideae	100-500
Indian alder	*Alnus nepalensis* D.Don	Betulaceae	-
Stylo	*Stylosantes* spp.		20-263
Horse bean	*Vicia faba* L.	Fabaceae	45–552
Pigeon pea	*Cajanus cajan* L. Mill sp.		68-88
Cowpea	*Vigna sinensis* L.Walp.		73–354
Blackgram	*Vigna mungo* L.Hepper		63–342
Soybean	*Glycine max* L.Merr.		60–168
Chickpea	*Cicera rietinum* L.		103
Lentil	*Lens esculenta* Moench		88–114
Ground nut	*Arachis hypogaea* L.		72–124
Pea	*Pisum sativum* L.		55–77
Bean	*Phaseolus vulgaris*L.		40–70
Alfalfa,	*Medicago sativa*L.		229–290
Clover	*Trifolium* spp.		128–207
Sunn hemp	*Crotalaria juncea* L.		199–223
Wild tantan	*Desmanthus virgatus* (L.)Willd.		196–226
True indigo	*Indigofera tinctoria* L.		79
Newdhaincha	*Sesbania rostrata*		70–458
			(Source: Nair,1993; Silva and Uchida,2000)

Root biomass

Nutrients generated by fine root biomass are another important avenue for improving soil nutrient status. Trees devote a considerable amount of their gross primary output to belowground processes such as the formation and maintenance of roots and mycorrhizae (Nair *et al.,* 2009). This allocation increases soil organic carbon and improves soil characteristics. However, there is little information on the quantity of nutrients delivered by roots in agroforestry systems. As a result, this article focusses exclusively on nutrients recycled from aboveground biomass.

Nutrient pumping

Trees can increase nutrient inputs to agroforestry systems by retrieving nutrients from lower soil layers and weathering rock. Most trees' deep roots properties are frequently highlighted as beneficial in agroforestry systems. As a result, trees may collect nutrients from soil depths beyond crop roots' reach. However, data is required to support this. The majority of the fine, feeder roots of many common trees are found in the 20cm deep topsoil. Uptake from deep soil layers and weathering rock is extremely probable, but difficult to demonstrate since minerals in weathering cannot be labelled. Indirect evidence includes tree roots penetrating weathering rock and certain trees growing in areas with little soil. Atmosphere deposition makes asignificant contribution to nutrient cycling, greater in humid regions than dry. It comprises nutrients dissolved in rainfall and those carried in dust.

In general, agroforestry activities increase soil organic matter by adding leaf litter, which increases the population of beneficial microorganisms and improves biological nitrogen fixation in soil. The addition of organic matter provides energy and improves nutrient cycling in the soil. Furthermore, it regulates soil microclimate and enhances the soil aggregate system.

Erosion control

Land degradation has direct consequences, including reduced soil productivity and food and cash crop shortages. In India, 175 million hectares of land have been deteriorated due to different concerns such as soil erosion and land degradation, especially during the rainy season. These concerns are key sources of land degradation and soil nitrogen loss (Mishra and Rai, 2013). This degradation process not only affects the land and soil but also leads to the loss of biodiversity and essential natural resources. Agroforestry systems have been shown to reduce nitrogen loss by 20% through a 1 to 10% reduction in soil erosion (Udawatta *et al.,* 2002).

CONCLUSION

Nutrient cycling varies across different land-use systems, influenced by factors such as terrain, tree species, and crop types. Leguminous trees stand out as particularly beneficial for field crops because they enhance nutrient cycling efficiency. These trees, which require substantial nutrient inputs while minimizing nutrient loss, support better nutrient absorption and management in agroforestry systems. This improved nutrient utilization contributes to higher soil organic matter levels, leading to enhanced nutrient cycling and increased soil productivity.

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ISSN : 2583-0910
Agri-India TODAY
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Article ID : 04/IX/29/0924

PLANT BASED MEAT: NOURISHING A SUSTAINABLE FUTURE

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Introduction

There is a growing awareness that fostering the transition toward plant-based diets with reduced meat consumption. Animal based agriculture presents a major sustainability challenges. Additionally, high consumption rates of some animal products is associated with elevated human health risks. Alternative meat products are substitutes for animal meat products, made using innovative food technologies. Plant-based meat are products designed to mimic the taste, texture and appearance of conventional animal-derived meats which can function as a direct replacement for meat while being entirely made from plant-based ingredients. Plant-based meats are a great way to add yet another form of protein to your diet. Advancements in the processing techniques have resulted in the development of meat analogue with improved nutritional quality and physicochemical attributes. The introduction of meat replacement in food products also known as meat analogue (also termed as imitation meat and mock meat).

Plant Based Meat for Growing World

Improving the efficiency of the Western diet is crucial to achieving sustainability. Plant-based meat allows consumers to enjoy the taste of meat at a fraction of the environmental cost. Plant based meat products are made from plant proteins such as soya, pea, nuts, oats and mycoproteins, designed to mimic the taste and texture of their animal-based counterparts (namely meat, milk and other dairy products). They have slowly, but steadily, increased their market share, with many of the leading supermarkets expanding their range of available products. Some of the most prominent players in the plant-based meat industry are Beyond Meat and Impossible Foods, which produce burgers, patties, sausages, nuggets, and other products that resemble animal meat. The worldwide plant-based meat market is estimated to reach $14.9 billion by 2027, growing at a compound annual growth rate (CAGR) of 15% between 2020 and 2027.

Processing Technology

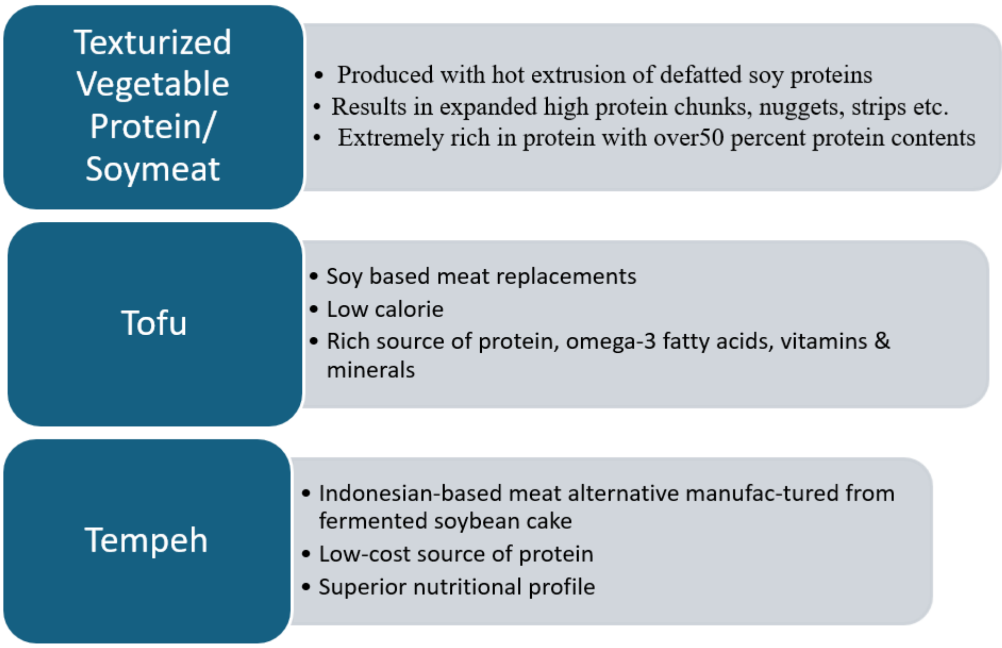
Plant-based meat products are typically processed using a combination of plant-based ingredients and various food processing techniques to mimic the taste, texture, and appearance of traditional meat. The overview of the processing steps involved;

- **Ingredient Selection**: Plant-based meat products start with selecting key ingredients like soybeans, peas, wheat, or other plant sources that provide the desired protein content and texture. High protein levels in the recipe are always associated with the good water binding capacity and improved rheological properties.
- **Protein Extraction**: Protein-rich ingredients are processed to extract proteins, such as soy protein isolate or pea protein concentrate. These proteins are vital for creating a meat-like texture.

- **Flavoring and Seasoning**: Ingredients like yeast extracts, spices, and flavorings are added to enhance the taste and aroma of the product, giving it a meaty flavor profile.
- **Texturization**: The extracted proteins are often texturized with extrusion (High temperature short time) processing to create a fibrous or meat-like texture.
- **Mixing and Forming**: The processed ingredients are mixed to form a dough-like consistency, which can then be shaped into various meat-like forms, such as burgers, sausages or nuggets.
- **Cooking:** The products are typically cooked by grilling, baking, or frying to improve flavor and texture.
- **Packaging**: After cooking, the plant-based meat products are packaged for distribution and sale.
- **Marketing**: Plant-based meat products are marketed as environmentally friendly and cruelty-free alternatives to conventional meat, often emphasizing their sustainability and health benefits.

Plant Based Meat Alternatives

The quality attributes of meat alternatives like consistency, taste, colour, etc. are based on the selection of ingredients. Meat alternatives have almost 50 - 80% water content, non-textured based protein 4–20%, vegetable textured based proteins 10 - 25%, additives for flavour enhancement 3–10%, fats 0–15%, colouring agents 0–5% and binding agents 1–15%. When these components or ingredients combine they provide meat alternatives with required sensorial and textural characteristics. Several types of meat alternatives are available globally with varied tastes, flavors and textures.



Pathway to Sustainable Food Supply

A global transition to "sustainable diets" typically high in plant-based and wholefoods while low in animal sourced foods having co-benefits for human health and environmental sustainability is being widely promoted. Plant-based meat is often viewed as a promising pathway to a more sustainable food supply for several reasons:

- **Reduced Environmental Impact**: Plant-based meats have less environmental footprint as compared to conventional animal agriculture. They require less land, water, and produce fewer greenhouse gas emissions. Plant-based meat can help to reduce deforestation, soil erosion, water pollution, and biodiversity loss that are often associated with animal agriculture. By choosing plant-based meat, consumers can support more sustainable and eco-friendly food systems that can benefit both people and the planet.
- **Diversified Food Supply**: Relying less on animal agriculture can help diversify our food supply, reducing the risk of zoonotic diseases and ensuring food security.
- **Resource Efficiency**: Producing plant-based meat typically requires fewer resources, making it a more efficient way to feed a growing global population. Plant-based meat alternatives can produce protein more efficiently and with less waste, which can help meet the growing demand for food in a world where resources are becoming scarcer.
- **Improving Health**: Plant-based meats can be lower in saturated fat and cholesterol, potentially promoting better health outcomes. Plant-based meat can also be more hygienic and safer than animal meat, as it does not contain hormones, antibiotics, or pathogens that can cause foodborne illnesses.
- **Ethical Considerations**: Plant-based meats offer a cruelty-free alternative to conventional meat production, addressing ethical concerns about animal welfare.
- **Promoting innovation and entrepreneurship:** The development of plant-based meat alternatives can stimulate innovation and entrepreneurship in the food industry. Many start-ups and established companies has drawn attention and investing in plant-based meat alternatives, which can create new jobs, products, and markets. This can also encourage the adoption of new technologies and practices that can improve sustainability and efficiency in the food system.

However, it's essential to continue researching and improving plant-based meat products to enhance their taste, nutritional profile, and affordability to make them a more widely accepted and accessible option for a sustainable food supply.

Conclusion

This shift toward plant-based meat is more than just a dietary trend; it's a vital step toward a greener, more sustainable future. Plant-based meat offers a promising solution to reduce the environmental impact of food production, provide a healthier alternative to traditional meat, and help feed a growing global population. Plant-based meat may very well be the key to unlocking a sustainable future for food and nutrition.

*"A step towards a healthier and more sustainable world is **plant-based meat ...**"*

ISSN : 2583-0910
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Article ID : 04/IX/30/0924

POND CONSTRUCTION IN SHRIMP FARMING OF NAGAPATTINAM AND MAYILADUTHURAI DISTRICTS

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Abstract
The construction of ponds is a fundamental aspect of shrimp farming, playing a crucial role in both enhancing productivity and ensuring environmental sustainability. In Nagapattinam and Mayiladuthurai districts, the process involves careful planning and execution, with key considerations such as site-specific design, water management, and environmental protection. Essential components include reservoir ponds, grow-out ponds, nursery ponds, and effluent treatment ponds, each designed to optimize water quality and support shrimp growth. The use of structures like dykes, sluice gates, and polyethylene-lined ponds is critical in addressing local challenges such as soil stability, flooding, and erosion. Additionally, the gradual adoption of nursery ponds highlights the region's commitment to improving productivity while maintaining ecological balance. This article explores the pond construction activities in Nagapattinam and Mayiladuthurai districts, focusing on methods and local practices essential for successful shrimp farming.

Keywords: Biosecurity measures, Dykes, Nursery pond, Pond construction.

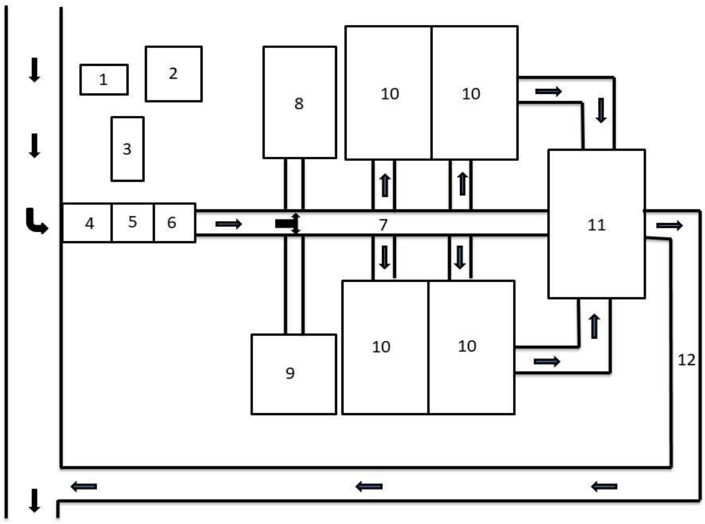
Introduction
Once the ideal site for shrimp farming is selected, the next required step is pond construction which ensures a suitable environment for optimal shrimp growth. It involves careful planning and engineering to create ponds with the right depth, shape and water retention capabilities. Proper designing and construction of shrimp farms are essential for their effective water management and for promoting environmental protection. Since site characteristics can vary greatly, a site-specific approach to farm design and construction is crucial, incorporating mitigatory features to address issues related to flood levels, storms, erosion, seepage and water management. It is important to choose coastal areas that are safe from flooding or storms, and to test soil stability before pond construction, as unstable soil can cause embankment erosion and water seepage.

In general, a shrimp farm will have reservoir ponds, grow-out ponds, nursery ponds and effluent treatment ponds. The design and layout of these ponds depend on the available space and specific needs of shrimp farming. If there is space constraints, biofloc tanks can serve as an alternative to nursery ponds. According to Coastal Aquaculture Authority (CAA) guidelines, 0.5 to 1.0 hectares is required for establishing a shrimp farm.

Fig 1: Pond construction work in Nagapattinam

Layout of shrimp farm

The layout is one of the most critical factors that determine the shrimp farm's efficiency, productivity and sustainability. A well-designed layout of shrimp farm not only optimizes the use of available space but also ensures effective water management, biosecurity and ease of operation. Key elements of a shrimp farm layout include water distribution and drainage system which is expected to ensure that water intake and discharge points are separate to avoid contamination and promote effective circulation. Sluice gates play a crucial role in controlling water flow in and out of the ponds, with their design being essential for preventing shrimp escape and efficiently managing water levels. The pond bottom should have an appropriate slope to facilitate easy drainage and harvesting, while strong pond bunds are essential to act as barriers that can hold water and withstand environmental pressures. Additionally, key infrastructures such as the powerhouse, pumphouse, feed storage sheds, workshops and security sheds should be strategically located for easy access and smooth operation, ensuring that all shrimp farming activities are well-coordinated.



1. Electricity room **2**. Feed storage room **3**. Labour room **4**. Water pump motor room **5**. First water filtration section **6**. Second water filtration section **7**. Water flow channel **8**. Reservoir pond **9**. Nursery pond **10**. Grow-out pond **11**. Effluent pond **12**. Water drainage channel

Fig 2: Shrimp farm layout

Key components in shrimp farm

Shrimp farms in Nagapattinam and Mayiladuthurai districts have a series of specialized ponds like reservoir, nursery, grow-out and effluent treatment ponds which are crucial for maintaining water quality, optimizing shrimp health and ensuring environmental sustainability. The percentages of area that constitute a shrimp farm are listed in Table 1.

Table 1: Percentage of area in shrimp farm

Key components	Percentage of area
Reservoir	20%
Grow-out Ponds	60%
Nursery Ponds	10%
Effluent treatment	10%

Reservoir pond

In shrimp farming practices across Nagapattinam and Mayiladuthurai districts, the reservoir pond area should range between 0.5 and 1 acre. These reservoir ponds are essential for improving water quality by settling water before it enters grow-out ponds. In these districts, the reservoir water distribution system involves sedimentation and in cases of disease outbreaks, the water may be treated with chlorination to eliminate pathogens. This process minimizes external contaminants that could disrupt shrimp survival, thereby maintains water quality at the beginning of the culture period and throughout the process by providing the necessary water replacements or additions.

In shrimp farming practices across Nagapattinam and Mayiladuthurai districts, the reservoir pond area should range between 0.5 and 1 acre. These reservoir ponds are essential for improving water quality by settling water before it enters grow-out ponds. In these districts, the reservoir water distribution system involves sedimentation and in cases of disease outbreaks, the water may be treated with chlorination to eliminate pathogens. This process minimizes external contaminants that could disrupt shrimp survival, thereby maintains water quality at the beginning of the culture period and throughout the process by providing the necessary water replacements or additions.

Nursery pond

One of the new advancements in shrimp farming is the establishment of nursery ponds. Nursery ponds are vital in shrimp farming as they provide a controlled environment for juvenile shrimp to grow, reducing mortality, managing diseases and ensuring optimal early development conditions before transferring them to grow-out ponds. In Nagapattinam district, many shrimp farmers have adopted this practice, setting up nursery pond on area of 0.5 acres, equipped with biosecurity measures and central drainage system. The entire pond is covered with a 750-micron polyethylene sheet to prevent leakage. In contrast, the implementation of nursery ponds in Mayiladuthurai district is relatively limited. Only a few shrimp farmers have adopted nursery pond compared to their counterparts in Nagapattinam.

Fig 3: Nursery pond in Nagapattinam

Grow-out pond

Rectangular or square ponds are considered appropriate for shrimp culture. In Nagapattinam and Mayiladuthurai districts, shrimp farmers prefer rectangular ponds due to their design, which maximizes natural aeration by aligning the longest axis parallel to the wind direction. This orientation enhances water movement, increases dissolved oxygen levels, and minimizes temperature fluctuations during the hot summer months. The grow-out ponds in these districts are typically semi-intensive, with size ranging from 0.5 to 1.0 hectares. Shrimps are raised from juveniles to marketable size in the grow-out pond. In these districts, the grow-out ponds are designed with minimum depth of 1 m and maximum depth of 1.5 m. Additionally, the pond bottoms are slightly sloped to facilitate easy draining and drying.

Fig 4: Grow-out pond in Nagapattinam

Effluent treatment

In Nagapattinam and Mayiladuthurai districts, effluent treatment pond (ETP) becomes an essential part of semi-intensive shrimp farms, when drainage water needs to be released back into the source creek. These ETPs in shrimp farms manage and treat wastewater, using processes like sedimentation and biological treatment to remove contaminants and excess nutrients from the water. Proper design and regular maintenance of ETPs are essential in these districts to ensure effective treatment and minimize environmental impact, supporting sustainable farming practices that align with local ecological needs.

Prominent structures in shrimp farm

Dykes

In shrimp farming, earthen and peripheral dykes play a critical role in managing water levels and protecting farms from environmental challenges. In Nagapattinam and Mayiladuthurai districts, the peripheral dyke is particularly crucial, as it protects shrimp farms from natural challenges like floods, tidal thrust and cyclones. In both Nagapattinam and Mayiladuthurai districts, where sandy coastal alluvium soil is predominant impervious materials such as concrete, clay are used as the core of the dyke. The structure of the peripheral dykes must take into account, the load-bearing capacity and compactability of the local soil. The height of the peripheral dyke should be at least 1.5 m to retain a maximum water depth of 1.0 m, with a slope that may range from 3:1 for sandy soils.

Sluice gate

In Nagapattinam and Mayiladuthurai districts, the use of sluice gates in shrimp farms is not as common as in other regions. Sluice gates, which are classified according to function as either main (primary) gates or secondary gates, are typically constructed from reinforced concrete and strategically situated at the perimeter of farms to control the quantity of water distributed to the shrimp ponds. However, many shrimp farms in these districts lack this sluice system. Instead, farm owners in Nagapattinam and Mayiladuthurai rely on motorized pumps to remove water from the ponds. The avoidance of sluice gate systems is primarily due to their susceptibility corrosive effects of saltwater, leading to frequent failures even after repairs.

Polyethylene-Lined Ponds

In both Nagapattinam and Mayiladuthurai districts, some of the shrimp farms are adopting the practice of covering ponds with polyethylene sheets to prevent soil contamination and water seepage. Polyethylene-lined ponds are particularly beneficial as they often incorporate drainage tanks instead of traditional sluices. Waste management is improved through the use of PVC pipes, which allows for more controlled and efficient drainage compared to conventional earthen ponds. By utilizing polyethylene sheets, shrimp farms in both districts can maintain the ponds for three to five years. This practice is highly effective in minimizing soil erosion and pollution. While this method is more commonly implemented in Mayiladuthurai district, it is gradually gaining traction in Nagapattinam district as well.

Conclusion

Pond construction in Nagapattinam and Mayiladuthurai districts represents a blend of conventional methods and modern techniques, specifically designed to address the region's unique environmental requirements. From carefully planned pond construction to the use of dykes, sluice gates and polyethylene-lined ponds, every aspect of the farm layout is designed to optimize shrimp growth while ensuring environmental sustainability. The local adaptation of practices such as the preference for rectangular ponds and the gradual adoption of nursery ponds, reflects the shrimp farmers' commitment to improving productivity and reducing ecological impact. As these districts continue to refine their shrimp farming techniques, the emphasis on site-specific solutions and sustainable practices will remain crucial for the long-term success and resilience of the industry.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/31/0924

SEXUAL CANNIBALISM: WHEN AND HOW IT IS ADAPTIVE

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Abstract

Predatory invertebrates frequently engage in sexual cannibalism, an extreme form of mating activity in which the female consumes the male either right before, during, or after copulation. Fundamentally, sexual conflict arises from the manner in which males and females optimise their reproductive success, resulting in traits that may be advantageous to one sex but detrimental to the other. Male and female reproductive strategies frequently diverge, leading to differential reproduction costs for both sexes and the ensuing conflict between them. In species where sexual cannibalism occurs, sexual conflict and antagonistic coevolution are significant, and may differ with regard to control over the duration of copulation and remating. Males may be able to counterbalance the expense of cannibalism if parts of their bodies are directly transferred to the eggs they fertilise, according to the theory behind the development of sexual cannibalism.

Introduction

The ability for living things to replicate themselves like carbon copies existed around 1.3 billion years ago through asexual reproduction. They were all true to type, with very little genetic diversity that could only be accounted for by random genetic mutation. As a result, there was reduced population variability. Through the incredibly effective mechanism of sex evolution, animals were able to adapt to ever-changing surroundings. Through sexual reproduction, an organism can mix half of its genes with half of another's, leading to new population variations.

Sexual reproduction was termed as beneficial process over asexual reproduction as the shuffling and recombination of genes created higher variations which proved to give better chance of offspring survival in the ever-changing environment. With improved adaptations over many generations, the species was able to flourish due to genetic variety. Costs associated with this evolution lead to conflict between the sexes and might eventually lead to sexual cannibalism. A female organism that kills and eats a conspecific male before, during, or after copulation is known as sexual cannibalism. While various types of cannibalism are common in many animal groups, arachnids, insects and amphipods have a long history of sexual cannibalism. Higher creatures such as octopuses and anacondas are also known to engage in this kind of cannibalism.

Sexual cannibalism

Intersexual predation of a male by female conspecific during courtship, copulation or immediately after mating is known as sexual cannibalism. Sexual cannibalism can be observed regardless of the food amount or population density. This behaviour is triggered by the victim availability and/or behaviour and it also has altruism mechanism. Types of sexual cannibalism are pre copulatory, copulatory and post copulatory.

ISSN : 2583-0910
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Sexual reproduction in praying mantis involves killing and consumption of all or part of a conspecific male (fig. 1). Historically, this was considered as an uncommon and incidental phenomenon of little ecological or evolutionary significance. Among the Arthropoda, cannibalism is usually related to carnivorous insects due to the existence of a structure adapted for the predator-prey relationship including mechanisms to localize the victim, strategies to attack, capture and kill the prey and a biochemical and physiological structure to digest and absorb animal tissue. Cannibalism among non-carnivorous (fig. 2) insects occurs in about 130 species in the orders Orthoptera, Blattodea, Hemiptera, Coleoptera, Hymenoptera and Lepidoptera.

Factors influencing sexual cannibalism

The factors which influence are ecological factors and phylogenetic factors. High mate availability and low food availability are two main aspects which comes under the ecological factors. When there is low food availability, the females tend to cannibalise its potential mates as adaptive foraging technique rather than considering them as a mate. Whereas, when there is high mate availability, it gives rise to two possibilities *i.e.,* from female perspective, the female will be more motivated to devour its male conspecifics without the fear of running out of mates. Wherein, from male perspective, if there are more females to mate with, it will motivate the males to escape cannibalism.

Fig. 1: Sexual cannibalism in praying mantis

Fig. 2: Sexual cannibalism in non-carnivorous insects

Due to these aspects of low food availability and high mate availability, female motivation to devour potential males and male motivation to escape cannibalism will influence the frequency of cannibalism. Whereas phylogenetic factors include predator feeding behaviour, vulnerable mating positions, genetic correlation and sexual size dimorphism where females will be larger than the males giving them an advantage over the male counter parts which are small in size comparatively will showcase male vulnerability.

Female and male adaptations

Many hypotheses were proposed to prove the adaptivity and evolution of sexual cannibalism in insects and spiders. These hypotheses may not hold good for all the species and different species adopted different hypothesis to justify the reason for sexual cannibalism existing in that species. These hypotheses on sexual cannibalism can be divided into two perspectives: Female perspective and Male perspective.

Female perspective includes aggressive spill over hypothesis, mate choice and adaptive foraging hypothesis. The aggressive spill over hypothesis suggests that the more aggressive a female is concerning a prey, the more likely the female will cannibalize a potential mate. The decision of female devouring the male does not depend on the nutritional value or genetics of the male but rather purely on aggressive nature of the organism alone. Females exercise mate choice, rejecting unwanted and unfit males by cannibalizing them. Mate choice often correlates size with fitness level. Smaller males tend to be less aggressive and display a low level of fitness. Usually, body size along with other courtship display will determine the male fitness level. According to adaptive foraging hypothesis, the female will cannibalize the male during copulation or just after copulation. The females assess the nutritional value of a male compared to the male's value as a mate to decide whether to devour the male or not. Cannibalism will increase the overall growth, body condition and fecundity of the female. Starving female which are in poor physical condition and females which are mated before are more likely to cannibalize the copulating males.

Male perspective includes paternal effort and mating effort. Paternal effort is the total reproductive effort devoted to parental investment. The main aim of the male is to give nourishment to the offspring via nourishing the female. A male gain by increasing the proportion of eggs he fertilizes from a given female or by increased mating opportunities. In this type of mating, the males try to extend the copulation duration and sperm transfer rate by self-sacrificing or by nuptial gifting. The mating effort done by the males will depict the percentage of success it gains in fertilizing more eggs with high sperm transfer with the help of self-sacrifice during copulation.

Measures to overcome sexual cannibalism

Antagonistic co-evolution has occurred, where adaptations seen in one sex produce adaptations in the other. Male members of different species have adapted various tactics to overcome sexual cannibalism. Some of the well know tactics to overcome sexual cannibalism are:

- **Opportunistic mating**: The males waits until the female is feeding or distracted and then proceeds with copulation; this greatly reduces the chance of cannibalization
- **Altered sexual approach**: The males will approach the female when there is disturbance to avoid getting noticed and mounts on it from rear.
- **Mate guarding**: The males will block the genital openings of female to inhibit other males from copulating and guard the males.
- **Catapulting away**: The males will catapult away from the females as soon as they finish copulating thereby reducing sexual cannibalism.
- **Male induced cataleptic state**: The males of this species will release knockout pheromone to sedate the female and copulate with them when they are unconscious.
- **Copulatory silk wrapping**: The males here will bind the leg I and leg II of female using silk threads while holding leg III and IV to avoid the female from cannibalizing them.
- **Nuptial gifting**: The males will gift food and copulate safely and for longer duration when the female is busy with the gift.

The cost and benefits

Reproductive strategies of males and females often differ, resulting in asymmetric costs of reproduction on the two sexes and a consequent conflict between the sexes. The cost and fitness can be prioritized based on the gender. Female costs include genital plugging by male, fertilization by a single male. Whereas, benefits are increase in physical condition and higher quality offspring. Male costs are death by sexual cannibalism (pre-copulatory or post-copulatory) and benefits includes increase in sperm transfer and paternal investment.

Conclusion

Males and females often face differing reproductive costs, leading to sexual conflict and antagonistic coevolution, particularly in species with sexual cannibalism. This phenomenon varies widely across species and contexts, influencing sexual selection differently. In some species, males may become more selective, while females may use cannibalism to eliminate unwanted mates and gain nutrition. The frequency of sexual cannibalism and its adaptive value differ, with some cases reflecting maladaptive behavior where females mistakenly consume mates due to hunger.

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Article ID : 04/IX/32/0924

AN INTRODUCTION TO AGRICULTURE ROBOTS AND THEIR REVOLUTIONARY USES

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Introduction

An agricultural robot is a robot that is used for agricultural applications. The main application of robots in agriculture today is harvesting. Weed control, cloud seeding, seed planting, harvesting, environmental monitoring, and soil analysis are some of the emerging applications of robots or drones in agriculture. Fruit picking robots, driverless tractor/sprayers, and sheep shearing robots are intended to replace human labour. In most circumstances, several elements must be addressed before beginning a work (for example, the size and colour of the fruit to be plucked). Robots can also be employed for horticultural duties like trimming, weeding, spraying, and monitoring. Robots can also be utilised in livestock applications (livestock robotics), including mechanised milking, washing, and castration. These robots provide numerous advantages for the agricultural industry, including greater quality fresh food, lower production costs, and a reduction in the demand for physical labour. The worldwide annual market for agricultural robots was estimated to be USD 24.5 billion in 2021. It was projected to grow to USD 74.5 billion in 2024, according to a report published on Statista.

Development

The initial development of robotics in agriculture dates back to the 1920s, when research into incorporating autonomous vehicle guidance into agricultural began. This research resulted in advances in autonomous agricultural vehicles in the 1950s and 1960s. The concept was not flawless, as the cars still need a cable system to guide their path. As technologies in other sectors advanced, so did agricultural robots. Machine vision guiding became conceivable only in the 1980s, after the computer was developed.

While robots have been used in indoor industrial settings for decades, outdoor robots for agricultural purposes are regarded as more sophisticated and harder to design. This is owing to worries about both safety and the complexity of selecting crops in the face of various environmental circumstances and unpredictability.

Need for Agriculture Robot

With an ageing population, Japan is unable to meet the demands of the agricultural labour market. Similarly, the United States currently depends on a large number of immigrant workers, but with the decrease in seasonal farmworkers and increased efforts to stop immigration by the government, they are also unable to meet the demand. Businesses are frequently compelled to let crops decay because they are unable to harvest them completely by the end of the season. Additionally, there are concerns about the expanding population that will need to be fed in the next years. As a result, there is a strong desire to enhance agricultural machinery in order to make it more cost effective and sustainable for long-term use.

Types of Agricultural Robots

Technology is nothing new in the sector. For millennia, farmers have sought strategies to boost output while reducing the number of farm laborer's required per acre. From horse-drawn ploughs to more recent technologies like planters, bailers, threshers, and harvesters, vital jobs have always been performed on a large scale. Some agricultural robots are self-contained tractors that pull traditional machinery, while others integrate robotics into current machinery. Various mechanical equipment for large-scale harvesting already exist; the difficulty is making those units autonomous. Frank W Andrew made the first attempt to develop a radio tractor in 1940. Eighty-one years later, John Deere, a long-time producer of farming machinery, acquired autonomous tractor company Bear Flag Robotics, heralding the start of a new era of autonomous tractors. Building on advances in self-driving automobiles, many farmers are now starting their shift to autonomous farming with this new type of tractor.

Applications of Robots in Agriculture

1. **Seeding and Planting:** Seeding and planting have historically been done by hand or tractor, which can be imprecise and result in seed waste. Many academics are working on different types of planting robots, including a DIY seed-sowing robot. Fendt extends the concept by deploying a swarm of small seeding robots to cover large areas of land in a systematic manner.
2. **Spraying:** Agriculture robots that spray fertilizers and pesticides use a technology called spot spraying, which employs AI to determine where to spray. This method decreases chemical usage, saves money, and reduces environmental impact while increasing effectiveness.
3. **Harvesting:** The next generation of harvesting robots utilizes image analysis and artificial intelligence to delicately pluck fragile crops like strawberries and lettuce. These agricultural robots not only harvest crops, but also differentiate between ripe and unripe product in order to maximize yield.
4. **Weeding and Mowing:** Some mechanical weeders just churn up the dirt around the plant and are simpler to automate. Sensors, on the other hand, have enabled developers to imbue their weeding robots with intelligence capable of distinguishing between crops and invading species while just eradicating weeds. These intelligent weeders can reach closer to the plant without hurting it and eradicate nutrient-hogging weeds more effectively. Carbon Robotics goes a step farther by employing lasers to kill weeds while avoiding crops.
5. **Transporting, Lifting and Towing:** Offloading to robots makes transportation a little easier. Whether it's loading crates of newly picked blueberries onto a truck or hauling zucchini containers, minimising the stress of lifting, carrying and dragging puts less strain on humans.
6. **Inspection and Monitoring:** Agriculture robots inspect and monitor soil moisture, pollution levels, fertilisation, pests, disease, and other variables. Robots take readings, inspect plants for signs of disease, decide when to harvest crops, and increase crop productivity.

Benefits of Robots in Agriculture

1. **Productivity** – Robots can work quicker than humans and for longer periods without a reduction in productivity, risk of injury or a need for breaks.
2. **Guaranteed workers** – With seasonal tasks like fruit-picking it can be difficult to find the staff on time, whereas robots are available to pick the produce when it is ready with no risk of a crop being left in the ground to rot.

3. **Waste reduction** – If crops are left in the ground due to staff shortages, or they are not palletised in time for distribution this can result in wasted crops. This won't happen with automation.
4. **Precision** – Robots are not susceptible to human error and therefore repetitive jobs (and even more complex tasks) will be done accurately and precisely throughout the entire process.
5. **Cost effective** – Although the outlay could be high, with robots running 24/7 this investment is quickly returned, as farms will be working more efficiently, with reduced waste, reduced labour and reduced running costs.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/33/0924

CLIMATE CHANGE AND AGRICULTURAL DISTRESS: A DEEP DIVE INTO FARMER SUICIDES AND SOLUTIONS

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Abstract

Agricultural distress, farmer suicides, and climate change are interlinked crises that have profound socio-economic and environmental implications. In many agrarian economies, particularly in developing countries, the farming community faces increasing vulnerability due to erratic weather patterns, diminishing yields, and escalating debt. Climate change exacerbates these challenges through unpredictable rainfall, extended droughts, and extreme weather events, which disrupt traditional farming cycles and lead to crop failures. The financial instability resulting from these factors often drives farmers into cycles of debt, leading to psychological stress and, tragically, a rise in farmer suicides. This paper examines the intersection of agricultural distress and climate change, focusing on the socio-economic conditions that lead to such despair. It explores the role of institutional support systems, government interventions, and sustainable agricultural practices in addressing these crises. By analysing data trends, this study highlights the urgent need for climate-resilient farming strategies, equitable financial policies, and policy support to mitigate the cascading effects of agricultural distress on farming communities. Addressing these interconnected issues is crucial not only for food security but also for the well-being of millions dependent on agriculture as a livelihood.

Introduction

The agricultural sector in India has long faced numerous challenges, including the impacts of climate change and environmental degradation. These issues are further compounded by declining soil fertility and water shortages, which present serious risks to sustainable agricultural output and necessitate the adoption of innovative practices and sustainable resource management. Additionally, rapid urbanization and soil erosion are leading to a significant reduction in arable land, emphasizing the urgent need for strategies that preserve existing farmland while strengthening agricultural systems' resilience to climate-induced pressures (Gupta *et al*., 2023). As India's population is projected to reach approximately 750 million by 2050, the challenge of ensuring food security becomes more critical. This situation is aggravated by the agricultural sector's current rate of resource consumption, which is 50% faster than what is sustainable, highlighting the need for a profound shift towards sustainable farming methods to safeguard both food security and environmental integrity (Pandia *et al*., 2019).

A promising approach to tackling these complex issues is the adoption of "climate-smart" agriculture, which involves strategies and technologies aimed at enhancing productivity, building resilience, and reducing the environmental footprint of farming. Implementing climate-smart measures, such as drought-resistant crop varieties, advanced irrigation techniques, and sustainable land management practices, can help farmers adapt to shifting climate conditions while minimizing their carbon footprint. Moreover, a collaborative effort involving policymakers, agricultural researchers, and local farmers is essential to scaling these practices effectively. This collaboration ensures that solutions are tailored to regional conditions and the socio-economic realities of India's farming communities. In this context, the importance of efficient water management cannot be overstated, as it addresses immediate irrigation needs and contributes to long-term sustainability by reducing water use and improving crop resilience against climate extremes like droughts and floods. To meet these objectives, it is crucial to prioritize less water-intensive cropping systems and promote sustainable agricultural practices that balance food security with environmental sustainability amidst the challenges of climate variability and rapid population growth.

The interconnection between climate and agriculture is closely tied to global processes. Even minor climate shifts can have negative effects on agriculture, reducing production rates. Global warming, which increases average atmospheric temperatures, has emerged as a significant trend reshaping the global future. In 1972, the Club of Rome report officially identified global warming as an international concern. Subsequently, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) declared carbon dioxide (CO2) as the primary contributor to climate change due to its substantial role in global warming. Assessing the effects of global climate change on agriculture is essential to adapting farming practices and enhancing agricultural productivity.

India and climate change

India contributes 10% of global agricultural output and stands as the second-largest producer of rice and wheat. It is also the world's largest consumer of groundwater, with its 260 million farmers heavily reliant on diminishing water reserves for irrigation. This dependency makes them particularly vulnerable to climate change, especially given that around 65% of India's cropped area relies on rainwater. The agricultural sector is increasingly affected by erratic rainfall and shorter winters, leading to reduced yields. Heavy rainfall results in flooding, while sudden temperature spikes, like those seen last year, have caused wheat grains to shrink. According to the Indian Council of Agricultural Research (ICAR), every 1°C rise in temperature leads to a significant reduction in wheat production, estimated at 4-5 million tonnes.

Global warming plays a critical role in these challenges. Historically, extreme heat events in the Indian subcontinent occurred roughly every 30 years as a natural phenomenon. However, due to human-induced climate change, such heatwaves are now far more frequent (Rosenzweig *et al*., 2007). Since 1992, over 24,000 heatwave-related deaths have been recorded in India, with the May 1998 heatwave alone claiming over 3,058 lives. More recently, in April 2023, temperatures in Delhi soared above 40°C, damaging crops and straining energy supplies in several states. According to the UN's Intergovernmental Panel on Climate Change (IPCC), India is projected to be among the countries most severely affected by the climate crisis in the coming years, with nearly 9% of its GDP at risk. The study warns that underestimating the impact of climate change could undermine efforts to reduce poverty, eliminate hunger, stimulate economic growth, and protect biodiversity. Extreme heat not only intensifies drought by drying out soil and altering rainfall patterns but also severely damages crops. For India, with its predominantly rural economy, productivity losses in agriculture pose significant threats to the livelihoods, health, and adaptability of millions of small and marginal farmers. If climate change is not effectively mitigated, increased heat could reduce India's GDP by 2.8% by 2050 and 8.7% by 2100, leading to a sharp decline in living standards.

Climate change impacts

Globally, the climate crisis was driving up costs and uncertainty for agriculture, and farmers in South Asian countries like India were especially vulnerable. Food production in Africa and South Asia was expected to be Farmers in India had been left reeling from extreme weather events in the first six months of 2022. In March, wheat fields in India shrivelled under one of the driest and most intense heatwaves since 1901, sparking fears that yields would fall by 10% to 50%. By May, the Indian government announced a ban on wheat exports, dealing a further blow to global wheat supplies already threatened by Russia's war in Ukraine. In India's dairy farms, heat stress resulted in falling milk production. At the same time, agriculture was also a significant source of greenhouse gas emissions. The sustainability of agriculture could be affected through climate change's impacts on biotic (such as pest and pathogens outbreaks) and abiotic factors (such as variation in solar radiation, water, and temperature). Floods caused by extreme rain in India had tripled over the past few decades, while cyclones in the Arabian Sea had risen by more than 50%. Climate change was making early and persistent heatwaves 30 times more likely. By 2050, India's average annual temperatures were expected to rise by 1°C to 2°C, even if mitigation measures were taken. Globally, pests-related yield losses for three major staple grains – rice, wheat, and maize – were projected to increase by 10-25% per degree of global mean surface warming. Changing rainfall patterns, especially increased variability, and unpredictability of monsoon rains, disrupted established cropping systems, and damaged crops. One study suggested that a 19% decrease in monsoon rainfall could cut food grain production in India by about 18%. With monsoon rains becoming more erratic, farmers were increasingly turning to, and fast depleting, groundwater. Even traditionally well-irrigated regions in the northwest and southeast of India were experiencing groundwater depletion, with some areas developing desert-like conditions. In Punjab, groundwater was being overdrawn by 14 billion cubic metres each year. On the other hand, more intense rainfall in other parts of India had led to increasing surface runoff and further depletion of soil nutrients.

Debt driven suicides

The issue of farmer suicides in India is a significant concern that undermines the potential benefits of the country's demographic dividend. The causes are multifaceted, ranging from monsoon failures, climate change, and rising debt burdens to government policies, mental health struggles, and family issues.

Rising Input Costs

One of the primary drivers of farmer suicides is the escalating cost of agricultural inputs. Over the years, the cost of cultivating crops like wheat has tripled since 2005. The prices of fertilizers, pesticides, and seeds have surged, making farming increasingly unaffordable for already indebted farmers. Additionally, the costs of agricultural equipment and machinery, such as tractors and submersible pumps, have also risen, further straining small and marginal farmers. Labor costs have also increased, driven by government programs like MGNREGA and higher minimum wage rates, which, while benefiting laborers, have added financial pressure on farmers.

Loan-Related Distress

Indebtedness is a critical factor in farmer suicides. According to NCRB data, in 2,474 out of 3,000 farmer suicides studied in 2015, the victims had unpaid loans from local banks. Although the debate on whether banks harassed these farmers continues, the correlation between debt and suicides is evident. Interestingly, only 9.8% of the loans were from moneylenders, challenging the perception that informal lending is the primary driver of suicides. The states with the highest farmer suicides, such as Maharashtra and Karnataka, also have high levels of indebtedness, underscoring the connection between financial strain and these tragedies.

Market Integration Challenges

Despite initiatives like the National Agricultural Market and contract farming that aim to connect farmers directly to markets, many farmers still face challenges due to limited market access and the persistence of intermediaries. The digital divide and literacy gap exacerbate these issues, leaving small and marginal farmers unable to benefit fully from government schemes. This is reflected in unsustainable cropping practices, such as sugarcane cultivation in water-scarce regions.

Water Crisis and Climate Change

Water scarcity plays a significant role in farmer suicides, particularly in drought-prone regions like Maharashtra and Karnataka. Failed monsoons have compounded the problem, leading to crop failures and economic distress. Interstate water disputes, such as the Kaveri River conflict between Karnataka and Tamil Nadu, further aggravate the crisis by limiting access to crucial water resources. Climate change has also exacerbated these issues, with unpredictable weather patterns leading to flash floods, delayed monsoons, and year-on-year production shortfalls.

Urban-Centric Economic Policies

India's economic policies tend to prioritize urban consumers over rural producers. For instance, when food prices rise, the government often imposes price controls, such as Minimum Export Prices or including items under the Essential Commodities Act, but is slow to withdraw these controls once prices stabilize. In contrast, sectors like steel receive protective measures like minimum import prices. This differential treatment of the agricultural sector limits profit margins and traps farmers in cycles of indebtedness.

Ineffective Policy Responses

Loan waivers are often used as a quick-fix solution to farmer indebtedness, as seen in the recent Rs. 36,000 crore loan waiver by the Uttar Pradesh government. However, these measures are temporary and fail to address the root causes of the crisis, such as crop failure and unsustainable farming practices. Without structural reforms that focus on reinvestment, productivity enhancement, and long-term financial resilience, such measures are unlikely to yield lasting improvements.

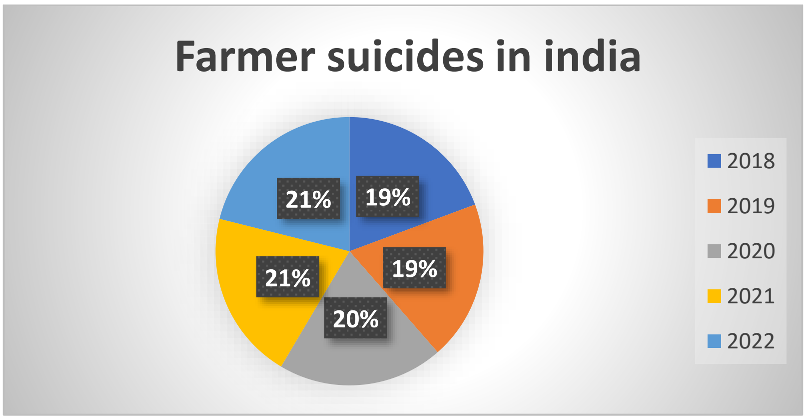

Fig. 2. Farmers suicide in India

Source: India National Crime Records Bureau • The data includes suicides among farmers, cultivators, and agricultural labourers.

Initiatives to Mitigate Farmers’ Distress

Farmers' Distress Index by CRIDA:

The Central Research Institute for Dryland Agriculture (CRIDA), operating under the Indian Council of Agricultural Research (ICAR), is pioneering the development of the "Farmers' Distress Index"—an innovative early warning system designed to predict and mitigate agrarian distress in India. This first-of-its-kind index aims to detect distress among farmers early, preventing its escalation from affecting an entire village or region. By providing central and state governments, local bodies, and non-governmental organizations with timely alerts, the index facilitates proactive interventions.

Objective:

The index primarily seeks to alleviate agricultural distress, often manifesting as crop failure or income shocks. Farmers have become increasingly vulnerable to such shocks due to rising extreme climate events and market fluctuations, which frequently contribute to farmer suicides.

The index assigns a value between 0 and 1 to represent the level of distress:
0 to 0.5: Low distress; 0.5 to 0.7: Moderate distress; Above 0.7: Severe distress
For severe distress levels, the index identifies the primary factors contributing to the problem.

Significance:

This system allows various agencies to tailor their interventions based on the severity of distress, focusing on preventing income shocks. Proposed solutions include direct financial transfers or interim payments under the government's crop insurance scheme for crop failures. For instance, under the Pradhan Mantri Fasal Bima Yojana (PMFBY), insurance claims are typically processed after a full survey. However, if the index predicts severe distress, the government could issue advance payments.

Pradhan Mantri Fasal Bima Yojana (PMFBY):

The Pradhan Mantri Fasal Bima Yojana, launched on February 18, 2016, is administered by the Ministry of Agriculture and Farmers Welfare. It offers comprehensive crop insurance, stabilizing farmers’ incomes by covering crop failures. The scheme covers food and oilseed crops as well as commercial/horticultural crops with available historical yield data.

Key Features:

- Farmers pay a premium of 2% for Kharif crops, 1.5% for Rabi crops, and 5% for commercial and horticultural crops.
- The government provides subsidies with no upper limit, covering up to 90% of the balance premium.
- The scheme is mandatory for loanee farmers with crop loans or Kisan Credit Cards (KCC) for notified crops and optional for others.
- Implementation is handled by empanelled general insurance companies, selected by state governments through bidding.

National Agricultural Market (e-NAM):

The e-NAM, launched in April 2016, is a nationwide electronic trading portal that aims to unify existing mandis into a single national market for agricultural commodities. It seeks to enhance agricultural marketing by standardizing processes across integrated markets and addressing information gaps between buyers and sellers, ensuring real-time price discovery.

Key Features:

- The platform allows contactless bidding and mobile-based payments, reducing the need for physical visits to mandis or banks.
- The Small Farmers Agribusiness Consortium (SFAC) serves as the lead agency for implementing e-NAM under the Ministry of Agriculture and Farmers' Welfare.

Soil Health Card Scheme:

Launched on December 5, 2015, by the Ministry of Agriculture and Farmers' Welfare, the Soil Health Card (SHC) Scheme provides farmers with a detailed report on the nutrient status of their soil across 12 key parameters, including pH, nitrogen, phosphorus, and potassium. SHCs are issued every three years to enable farmers to apply recommended doses of nutrients, thereby improving soil health, fertility, and crop productivity.

Key Features:

- SHCs provide farm-specific reports on soil fertility and other critical factors affecting productivity.
- Farmers can track their soil samples and obtain SHC reports through the scheme, promoting informed nutrient management for sustainable agriculture.

Conclusion

Adapting agriculture to climate change involves a multifaceted approach that integrates sustainable land management, crop diversification, and technological innovation. Key strategies include replacing water-intensive crops with less demanding varieties, adopting drought-tolerant and heat-resistant seeds, and implementing practices like conservation agriculture and micro-irrigation. In India, these adaptations are supported by government programs and initiatives aimed at improving water use efficiency, expanding irrigation, and providing risk management tools such as crop insurance. By embracing these methods, farmers can enhance resilience against climate impacts and sustain agricultural productivity.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/34/0924

PRECOOLING TECHNIQUES: APPROACH IN PROLONGING SHELF LIFE OF FRUITS AND VEGETABLES

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Introduction

In India, there is surplus production of fruits and vegetables contributed approximately 326.58 million metric tons in 2020-21. Despite abundant production, 30–40% loss of fruits and vegetables has been reported every year from harvesting to consumption. There are several factors *i.e.* inadequate infrastructure facilities, poor transportation, limited knowledge of post-harvest handling, market inefficiencies, and technological gaps *etc* contributed towards these losses. This is a significant issue for the Indian economy. Therefore, to extend their shelf life and maintain quality, we should employ scientific methods immediately after harvesting. Precooling is the rapid removal of field heat from fruit and vegetables in order to slow down the deteriorative process thereby increases its storage life, preserve the product's quality and market value. It has also been defined as the pre-storage cooling of fruits and vegetables immediately following harvest. This process allows fresh fruits and especially vegetables to maintain their optimal quality for an extended period, thereby preserving them for long-distance transportation. The major benefits of precooling are that it: 1) prevents or significantly slows down the deterioration of the product; 2) reduces shrivel and decay; 3) maintains fresh weight and appearance; and 4) enables the product to be transported without reducing quality.

Importance of Precooling in Fruits and Vegetables Preservation

Postharvest handling of horticultural crops is an important practice. A large number of fresh fruits and vegetables reaches to a deteriorated state before consumption especially during high temperature conditions. After harvesting, enzymes remain active in living tissue and exhibit certain physiological actions. Due to enzymatic action, pectocellulosic materials are broken down, crispness is lost, and texture is altered. The microbial activities may cause decay in the form of soft and wet rot. In order to reduce the effects, it is very essential to deactivate the tissue metabolically. The reduction of field heat from the harvested horticultural commodities to a safe, efficient, and temperature-dependent level (25–30°C usually) while maintaining product quality is done immediately after harvesting. This technique can delay or inhibit ripening and maintain the maturation process, reduce weight loss, and delay post-harvest decay. Generally, the temperature should be cooled down till it reaches 88% of the existing difference in temperature and its optimal storage temperature. To inhibit respiration and other metabolic activity and to extract the field heat, the precooling method must be properly designed and operated.

Mechanism of Pre-cooling

Precooling is achieved by using two mechanism of heat transfer. The first mechanism, conduction which is the direct transmission of heat from one medium to another. The second is convection in which heat is removed from the product's surface through a cooling medium such as air or moving water. Heat is also produced within crop by two ways: convection (from the environment) and respiration (metabolic heat produced by internal chemical reactions).

Factors affecting precooling efficiency

- Product size
- External surface resistance
- Heat removal in sap or vascular bound water
- Air cellular pores
- Available free water, starch, and soluble solids level
- External cooling levels
- Individual sensitivity to cooling, etc

Methods of Precooling

Room cooling

Room cooling is the simplest and most economical process employed for precooling of fruits and vegetables in a insulated cold-storage room. In this method product is simply loaded into a insulated cool room and air is allowed to circulate among the carton, sacks, bins or bulk load. Room cooling requires a short refrigeration unit therefore highly perishable commodities can't be cooled. It gives a slow and non-uniform temperature reduction. Although its energy requirement is very less but this process is very slow, therefore it is recommended for the crops that decays at slow rate.

Fig.1 Room cooling of Fruits

Source: stilfresh.co.uk/the-importance-of-pre-cooling-fruits-and-vegetables-before-export

Forced air cooling

In a forced-air cooling system, perishables are placed in bins or packages at the entrance of a tunnel or in a room cooled by high-velocity airflow transversally. This process is 90% faster than room cooling. Produce can be cooled using various forced air-cooling systems. These methods involve (a) circulating air at a high speed in refrigerated rooms, (b) forcing air through the empty spaces in large quantities of items as they pass through a cooling tunnel on moving conveyors, and (c) promoting the circulation of forced air through packed produce using the pressure differential technique. Forced-air cooling often employs recirculating air. In recirculating forced-air cooling, the removed field heat is concentrated in a small space and then removed by the air conditioner or desiccant dehumidification system (DDS) from the return air. The air flow can be arranged horizontally or vertically. Flow rate range of 0.5–2.0 L kg-1 s-1 and a pressure drop range of 60–750 Pa is recommended in industry for non-polylined horticulture produce. This technique is also known as *blast cooling*. This method is suitable for pre-cooling of packed berries and stone fruits.

Hydro-cooling

Hydrocooling is the method of pre-cooling fruits and vegetables with chilled or cold water by flooding, spraying/sprinkling over them, and immersion in a tank. This method is quicker than forced-air cooling as it has higher heat removal capacity approximately 5 times faster than air. Different types of hydrocooler are available in the market that have different cooling rates and overall process efficiencies. Mostly three types of hydrocoolers are employed: conventional (flood) type, immersion type, and batch type. Conventional hydrocoolers that cool the packaged product by flooding water when the product is conveyed through a cooling tunnel, whereas in batch systems spray chilled water over the product for a specific duration of time, depending on the type of product. These hydrocoolers have a smaller capacity and are less expensive. However, they may leave *'hot spots'* due to the uneven distribution of chilled water, resulting in undercooling. The bulk or immersion type cooler uses a combination of immersion and flood cooling, resulting in the most rapid hydrocooling. However, not all produce types, such as strawberries and cauliflower, can be hydrocooled because it can cause rapid spoilage. Hydrocooling requires careful attention to water quality and sanitation.

Fig No.2: Hydrocooling of carrots
Source: www.foodstandards.gov.scot

Vacuum precooling

Vacuum cooling is a method of pre-cooling in which fresh produce is placed in a vacuum chamber in which vacuum has been created by the evacuation of air. The technology aims to quickly remove the heat and reduce the temperature by utilizing the latent heat of vaporization of the water molecules without causing freezing. At reduced pressure of about 4.6 mm Hg, water on the surface of the produce evaporates quickly, which removes the field heat. Vacuum cooling typically exhibits faster and more uniform cooling than the conventional methods. It usually takes only 15-30 minutes, treating whole pallet loads of fresh produce, resulting in better retention of the quality and longer shelf life. One disadvantage of this method includes the reduction in crop weight of 1% for every 5 or 6 °C reduction in temperature. Vacuum coolers are expensive to purchase and operate, therefore they can only be used for the limited range of produce. Some steam, leafy, and flower-type vegetables can be cooled by this method.

Cryogenic cooling

The latent heat of vaporization of cryogenic substances (solid CO_2 (dry ice) or liquid nitrogen) is used to reduce the temperature of the products to the desired level. They generate boiling temperatures of -780 °C and -196°C for solid CO_2 (dry ice) and liquid nitrogen, respectively. In this process the produce is cooled by conveying it through a tunnel, where the liquid nitrogen or CO_2 evaporates. The temperature of the produce is continuously monitored to ensure that it reached the desired level. This process is relatively cheap to install but expensive to run, especially for cooling crops like soft fruits. The high cost of liquid nitrogen, dry ice, and non-toxic refrigerants makes it suitable for crops of high cost. Soft fruits like berries, leafy vegetables and vegetables that require rapid cooling are suitable for this method.

Ice-cooling

Ice cooling is a method used to cool produce by applying crushed or fine granular ice. Crushed ice is directly injected to packaged product /shipment containers that fills the voids around product. This process is faster than hydrocooling as ice has high heat removal capacity. The major advantage of ice-cooling is that produce does not dry when it is cooled, and it can maintain low product temperature during transit. However, icing requires large weights of ice, increasing costs, and requires more expensive water-proof containers. The application of this method is limited to produce that are not sensitive to wetting, wet produces are more sensitive to diseases. Asparagus, Broccoli, Onions (green), Parsnips, Radishes, Sweet Corn etc are suitable for this method.

Table No. 1 Comparison of Pre-cooling methods

Variables	Cooling Methods				
	Ice	**Hydro**	**Vacuum**	**Forced-air**	**Room**
Cooling times (h)	0.1-0.3	0.1-1.0	0.3-2.0	1.0-10.0	20-100
Water contact with the product	Yes	Yes	No	No	No
Product moisture loss (%)	0-0.5	0-0.5	2.0-4.0	0.1-2.0	0.1-2.0
Capital Cost	High	Low	Medium	Low	Low
Energy efficiency	Low	High	High	Low	Low

Source- Kader and Rolle, 2004

Innovations and Future Trends in Precooling Technologies

Precooling brings down both external and internal temperatures of fruits and vegetables to the maintaining temperature faster at which they can be stored. The proposed cooling technologies are mainly prepared by considering three factors which are constituting towards total heat load: transpiration, respiration, and heat exchange with the environment. Finally, the precooling rate depends on the magnitude of the total heat load, i.e., the rate of transpiration and respiration of fruits and vegetables and heat exchange capacity of the precooling medium. Hence, several researchers have proposed precooling technologies by concentrating on climacteric and non-climacteric factors.

A number of pre-cooling technologies have been developed over the past several years to reduce respiration and fruit temperature when it is harvested during high/low temperature days or brought to the packing house or in the market. Each technology has its advantages, disadvantages, and limitations. Immersion, contact, caldron or dip cooling, hydrocooling, cooling with vacuum chambers, hydro-vacuum precooling, vacuum cooling, and combinations of these and other technologies are among the most common methods currently used. Each of those methods has been shown to be efficient in reducing physiological disorders and both visible and internal quality loss of some fruits and vegetables and have been adopted technologies. Yet, the economic and ergonomic feasibility and practical completeness of the system and consumer preferences remains to be analyzed. As a result, there will be the potential for the use of precooling techniques for fruits and vegetables.

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Article ID : 04/IX/35/0924

THE RISE OF ELECTROSPRAY COATING IN FISH AND FISHERY PRODUCTS

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ABSTRACT

Fish, being highly perishable, requires immediate preservation post-catch to maintain its quality until it reaches consumers. Spraying is one of the efficient techniques of preserving the quality of meat products with minimal requirement compared to dip coating. Conventional spraying does not coat the product evenly whereas electro spraying methods yield fine droplets of less than 20µm resulting in thin and even coatings. It is based on the principle of ionization. This technique enables the ionization of a sample, turning it into charged ions by applying high voltage to a liquid, thereby producing aerosol. This method is used to enhance the viability of probiotics, improve the shelf life of fruit slices and also it is applied in various fields such as food packaging, water filtration, enzyme immobilization etc. This novel method of preservation may also be used to improve the shelf life of dried, refrigerated or frozen fish or fishery products which has more advantage than conventional spraying and dipping.

INTRODUCTION

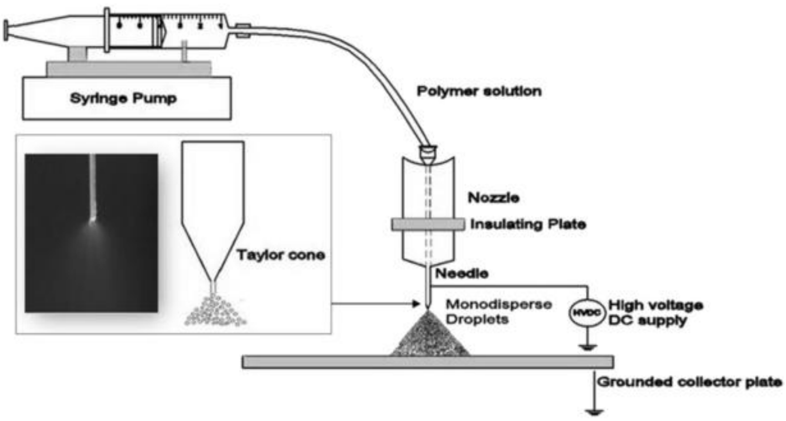
Fish is a highly perishable commodity, so it should be preserved as soon as it is caught. Spoilage of the meat product related to microorganisms, lipid content and autolytic enzymes. However, oxidation and denaturation of lipids and proteins are the principal spoilage mechanisms by microorganisms. Spoilage begins at the time of catch. It is necessary to maintain the quality of fish from the catch to when it reaches the consumer. Several methods of preservation techniques are followed to maintain the quality of fish and fishery products. Development of nanotechnology in the preservation of meat products can mask the unpleasant flavors and undesirable odors; also increased the shelf life of the product by providing protection against lipid and protein denaturation using some of the natural active ingredients (Saavedra et *et al.,* 2022)**.** The active ingredient consists of natural antioxidants which can delay the lipid oxidation and increase the shelf life of the perishable product even at low concentrations (Gomez *et al.,* 2018). The addition of antioxidants and essential oils in the preservation of value-added meat products involves procedures like spraying, marinating, injection or applying edible coating of antioxidants (Morcuende *et al.,* 2020). The process of extending the shelf life of the perishable product by using electrospray coating of essential components will be seen in this article.

Why Electrospray?

In the dipping process, the products are directly dipped into the solution of specific concentration for a particular period of time, which can extend the shelf life of the product with a major drawback that the solution needs to be changed frequently. Spraying is one of the efficient techniques of preserving the quality of meat products with minimal requirement compared to dip coating i.e. pork was preserved by spraying antimicrobials which showed better resistance of microbes than dipping method (Azevedo *et al.,* 2019). The efficient method of preservation is preservation by conventional spraying of antioxidants which could extend the shelf-life of the product without influencing product taste. Even though an efficient method, conventional spraying does not coat the product evenly. In order to combat this, a method is followed for preserving fruits and vegetables called electro spraying methods which yield fine droplets of less than 20µm resulting in thin and even coatings (Khan *et al*., 2012).

What is an Electrospray coating method?

The electrospray deposition system utilizes electrical forces for liquid atomization, generating a plume of droplets by charging the liquid at high voltage. These charged droplets are then sprayed from the nozzle tip. This system offers several advantages over conventional methods, including high drug loading efficiency and self-dispersion. Electrospray operates by attracting opposite charges and repelling similar ones (Hudson *et al*., 2019). When acid solutions are introduced into Electrospray nozzles, they become charged and break into smaller, more uniformly dispersed droplets. In contrast, traditional spray devices require large amounts of water to deliver antimicrobial agents, often fail to evenly cover all surfaces, particularly hard to reach niche areas (Shen *et al.,* 2019).



(Bhushani *et al*., 2014)

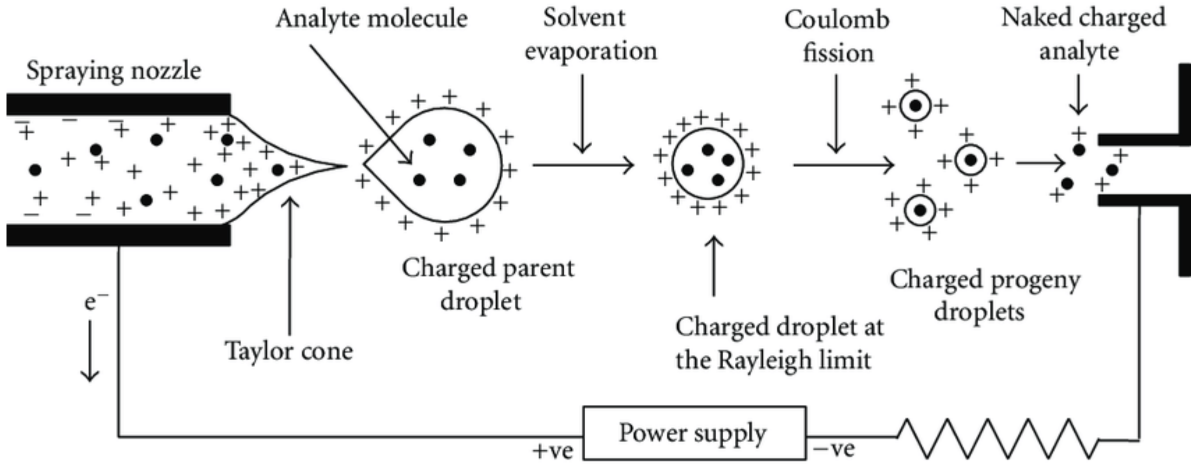
Principle and its working

It is based on the principle of ionization. This technique enables the ionization of a sample, turning it into charged ions by applying high voltage to a liquid, thereby producing aerosol that can be utilized in various chromatography techniques. Typically, ionizing molecules is challenging due to their fragile nature. The process involves applying high voltage to the capillary outlet, which atomizes the particles into tiny charged droplets. As the solvent evaporates, the charge intensity on the droplet increases, ultimately causing them to split into charged ions. These charged ions form the charged phase ions.

Electrospray Ionization Process can be in three distinct steps

1. Droplet formation occurs when the sample solution is ejected from the capillary and exposed to a high voltage electric field, causing the sample to form small, charged droplets.
2. Solvation involves the evaporation of these charged droplets by a counter current of heated gas, which decreases their diameter and, as a result, increases their surface charge density.

When this charge becomes too great, the internal repulsive forces exceed the surface tension, causing the droplets to undergo fission, or split into even smaller charged droplets.
3. Formation of gas phase ions happens when these tiny charged droplets reach the nanometer scale, effectively turning into gas phase ions.



(Banerjee *et al.*, 2012)

APPLICATION ON EDIBLE COATING AND ITS ADVANTAGES:

Electrospray coating was used to enhance the viability of freeze-dried probiotic strain, especially whey protein concentrates with ultrafine particles of hydrocolloids (Libran *et al.*, 2017). Pineapple slices were electro sprayed with pomegranate and grape seed oil rich emulsion which showed increased quality features of pineapple slices than the dip coating method (Albayrak *et al.*, 2023). Dextran was used in the encapsulation of baking enzyme, Hmxyn xylanase which showed 90% efficient recovery of enzymes; improved hydrogen bonding between dextran and xylanase and also showed improved storage stability (Zhang *et al.*, 2024). Thymol was encapsulated using the coaxial electrospray method with different flow rate ratios and concentrations, forming a protective three-dimensional network with zein and shellac which ensured controlled release and enhanced long-term storage (Liu *et al.*, 2023). Electro spraying process was Fish oil used as an encapsulation material to produce a multilayered microcapsule using a monolayered electrospray method that showed improved efficiency and enhanced the viability of probiotics (Huang *et al.*, 2021). It provides a simple way to ionize non-volatile solutions for both organics and bio macromolecules. The specific distribution of charge states provides both accurate molecular mass in addition to structural information. It can also provide multiple ionization modes, positive and negative. In this method, sustained and controlled release of food grade biopolymers are used to protect the product using a non-thermal process that results in efficient encapsulation and increased stability of natural bio actives.

ELECTROSPRAY IN FISHERY PRODUCTS

Furcellaran–gelatine coating with thyme and rosemary extract was used to extend the shelf life of refrigerated carp filets using dip treatment (Gedif *et al.*, 2023). Dip treatment using a mixture of antioxidants (sodium erythorbate and a polyphosphate mixture) for Atlantic mackerel increased the shelf life up to 15 months during frozen storage at -25°C (Sveinsdottir *et al.*, 2020). It may be prescribed that it is better to use electrospray coating for the preservation of fresh filets under refrigeration and frozen conditions and also for dried fish which may retain the quality and increase the shelf life of these perishable products. As mentioned above, dipping and other conventional spraying may not coat the product in a uniform layer whereas in electrospray coating, the bioactive compound will be uniformly coated which will reduce the number of bioactive compounds as well.

CONCLUSION

Electrospray coating is a novel technique which provides an efficient and uniform release of bioactive compounds in preserving the quality and extending the storage stability of food products with minimal concentration of the bioactive substances showing that it is a cheap and economical method. Being a non-thermal process method, it can maintain the nature of antioxidants without any denaturation. It not only plays a significant role in edible coating of food products but also plays a vital role in other fields such as food packaging, enzyme immobilization and also aids in water filtration.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/36/0924

GENETIC DIVERSITY: UNDERSTANDING LIVESTOCK VARIATION FOR BETTER BREEDING

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Abstract

Variation in livestock refers to the differences in physical characteristics, productivity, behaviour, and other traits observed among individuals within a livestock population. This variation can be influenced by several factors, including genetics, environment, and management practices. Understanding and managing this variation is crucial for livestock breeding, improvement, and overall farm productivity. Variation in livestock is influenced by genetic, environmental, phenotypic, and behavioural factors. Genetic variation arises from inherited traits and selective breeding, which shape traits like growth, milk production, and disease resistance. Environmental factors, such as nutrition, climate, and management practices, further affect livestock health and productivity. Phenotypic variation is seen in physical characteristics and productivity traits, while behavioural differences, such as temperament and feeding habits, also impact performance. Effective management of this variation through genetic testing, crossbreeding, and environmental management is crucial for improving livestock, enhancing adaptability, and increasing disease resistance.

Keywords: Phenotype, Genotype, Environment, Variation

Introduction

Phenotypic variation ($\sigma^2 p$) refers to the observable differences among individuals within a population for a specific trait, essential for effective animal breeding and selection. This variation arises from both genetic factors (genotype) and environmental influences, with variability often resulting from their interaction. While genetic factors are consistent and inherited, environmental influences introduce non-genetic differences. The total phenotypic variation is the sum of genetic variance (σ^2_G) and environmental variance (σ^2_E). Genetic variance itself comprises additive genetic variance (σ^2_A), dominance deviation variance (σ^2_D), and epistatic interaction variance (σ^2_I), each contributing to how traits are expressed. Understanding these components is crucial for making informed breeding decisions and improving livestock performance.

Phenotypic variation (σ^2_p)

Phenotypic variation refers to the observable or measurable differences among individuals within a population for a specific trait. This variation is essential for animal breeding, as it provides the basis for selection and culling. Without such differences, there would be no need for breeding decisions, as all animals would be identical in performance and appearance. Both genetic factors (genotype) and environmental influences contribute to these differences. Sometimes, variability results from the interaction between heredity and environment, making it challenging to pinpoint which portion of the variation is due to each factor. Environmental differences include non-genetic variations arising from management practices, nutrition, and climatic conditions.

$$\sigma^2_p = \sigma^2_G + \sigma^2_E$$

Hereditary variation or Genotypic variation (σ^2_G):
It refers to the portion of phenotypic variation in a population that is attributable to genetic differences. An animal's genotype, established at conception and remaining unchanged throughout life barring mutations, is determined by the genes inherited from its parents. This genetic makeup influences hereditary variation through various gene actions, both additive and non-additive. The genotypic variance can be divided into three components:

1. **Additive Genetic Variance (σ^2_A)**: Variance due to the cumulative effect of individual genes.
2. **Dominance Deviation Variance (σ^2_D)**: Variance resulting from interactions between alleles at a single gene locus.
3. **Epistatic Interaction Variance (σ^2_I)**: Variance due to interactions between different gene loci.

The total genotypic variance (σ^2_G) is the sum of these components: $\sigma^2_G = \sigma^2_A + \sigma^2_D + \sigma^2_I$. Epistatic variance represents the residual variance not explained by additive or dominance effect

Additive Genetic Variance (σ^2_A)
It refers to the portion of genetic variation in a trait those results from the sum of individual gene effects. In this model, each gene contributes a predictable increase or decrease to the trait, and these effects are simply additive. The variance associated with these additive effects, calculated by summing the contributions from all loci affecting the trait, is known as additive genetic variance. This model helps explain the phenotypic variability observed in traits where gene effects combine linearly.

Dominance Deviation Variance (σ^2_D)
Dominance occurs when the phenotype of a heterozygote differs from the average of the two homozygotes, indicating non-additive gene effects. In cases of complete dominance, much of the phenotypic variation can still be explained by additive effects, but any remaining variability not accounted for by these additive effects is due to dominance deviations. This variance arises when the phenotype of a heterozygote (Aa) is different from the midpoint between the homozygotes (AA and aa). Dominance can range from none (where Aa is equal to AA + aa/2) to over-dominance (where Aa exceeds AA).

Epistatic variance (σ^2_I)
This represents the residual genetic variance not explained by additive or dominance effects and results from interactions between non-allelic genes. It captures the variation due to the complex interplay of multiple genes beyond simple additive or dominance models.

Environmental Variation (σ^2_E)
The differences in economic traits caused by environmental factors are significant and are referred to as environmental variance, denoted by σ^2_E. Environmental factors encompass elements such as disease, nutrient supply, temperature, accidents, and management practices, affecting the individual from conception to death.

Environmental variation is crucial because:
1. It is not inherited by offspring.
2. It can often overshadow genetic variation.
3. Optimal environmental conditions are necessary for an individual to achieve its genetic potential.

4. Providing consistent and high-quality environmental conditions can lead to rapid improvements in livestock production efficiency.

Importance of Heredity and Environment

Both heredity and environment play crucial roles in the development of economic traits in livestock. Superior genetic potential alone will not lead to an outstanding herd or flock without an appropriate environment that allows animals to reach their genetic potential. Conversely, even the best environmental conditions cannot produce a superior herd or flock without favorable genetics. To maximize the benefits of good heredity, it is essential to select breeding animals with desirable genetic traits. While genetic superiority is inherited and passed on to offspring, environmental advantages are not transmitted. Breeders should be careful not to confuse the effects of environment with genetic differences when evaluating livestock.

Conclusion

Phenotypic variation, driven by both genetic (genotype) and environmental factors, is essential for effective animal breeding. Genetic variation, including additive, dominance, and epistatic components, shapes the potential traits of livestock, while environmental factors such as nutrition and management influence how these traits are expressed. To achieve optimal livestock performance, it's crucial to understand that both superior genetics and favorable environmental conditions are necessary. Breeding decisions should carefully balance these aspects to enhance productivity and efficiency.

Acknowledgement

The ChatGPT, an AI-powered chatbot (https://www.openai.com/chatgpt) was used for language modulation,

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ISSN : 2583-0910
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Article ID : 04/IX/37/0924

IDENTIFYING AND CORRECTING ZINC DEFICIENCY IN CROPS

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Abstract
Zinc deficiency in plants is becoming a growing concern, both for plant health and public health, especially children's health. Thus, zinc fertilization plays a crucial part in obtaining sufficient yield to feed the growing population, and improve the diet of billions, since the zinc in the plants is absorbed by humans. The present paper discusses the Zn importance in plants, its deficiency in soil, diagnosis and corrective measures for crop improvement.

Introduction
Optimal crop nutrition is a significant factor in increasing agricultural vintage and quality of products. Zinc (Zn) is an immobile important micronutrient, which is taken up by plants in Zn^{2+} form to complete their life cycle efficiently. It plays a critical metabolic role in plants and is an important constituent of proteins and other large-molecules, and serves as structural and functional unit, or controlling cofactor for a wide range of enzymes. The Zn is needed in small and in appropriate amounts for plants main physiological processes to work normally. These processes play critical roles in photosynthetic activity of plants and forming carbohydrates, synthesis of protein, reproduction and seed development, growth, and disease protection. After Zn deficiency in plants, these physical functions are decreased, and plant health and productivity suffer greatly, subsequent in reduced production or even failure of crops and often bad quality of crop products. Plant Zn deficiencies occur on variety of soils and are severe due to a combination of symptoms like chlorosis, resetting, dieback and suppressed or irregular vegetative development. In addition, various crops require varying amount of Zn. The present paper discusses the Zn importance in plants, its deficiency in soil and required level of Zn for crops.

Zinc deficiency effects both plant yield and human health. With the right fertilizers, zinc deficiency in plants can be overcome. With more than 9 billion people expected to populate earth by 2050, zinc deficiency in plants is becoming a growing concern, both for plant health and public health, especially children's health. Thus, zinc fertilization plays a crucial part in obtaining sufficient yield to feed the growing population, and improve the diet of billions, since the zinc in the plants is absorbed by humans.

Since hidden zinc deficiency can cause major yield loss, soil testing is the best method to assess zinc disorder. Plant tissue analysis, alongside visual inspection, is a complementary method. For example, maize that suffers from zinc deficiency will develop white or yellow stripes parallel to the midrib on the young leaves.

Factors Contributing to Zinc Deficiency
Generally, Zn deficiency is considered higher in the calcareous soil, sandy soils, and peat soils, and in soils that have a higher rate of phosphorus, calcium carbonates, and silicon. Salinity/Sodicity and

calcareousness of soil from arid to the semi-arid condition is directly related to Zn deficiency. In such soils only a small portion of Zn is available to plants for their proper growth while it is present in relatively higher concentrations. The soil conditions which most commonly give rise to deficiencies of zinc in crops can include one or more of the following:

- low total zinc concentrations (such as sandy soils),
- low pH, highly weathered parent materials with low total zinc contents (e.g. tropical soils),
- high calcium carbonate content (calcareous soils),
- neutral or alkaline pH (as in heavily limed soils or calcareous soils),
- high salt concentrations (saline soils),
- peat and muck (organic soils),
- high phosphate status,
- prolonged waterlogging or flooding (paddy rice soils),
- high magnesium and/or bicarbonate concentrations in soils or irrigation water.

Soils with one or more of these properties can be found in many areas of the world. Countries with particularly widespread zinc deficiency problems include: Afghanistan, Australia, Bangladesh, Brazil, China, India, Iran, Iraq, Pakistan, Philippines, Sudan, Syria, Turkey, many states in the USA and parts of Africa and Europe.

Mostly Zn deficiency problemsare found in calcareous, and weathered acidic soils. The adsorption of Zn from soil solution by clay and limestone particles causes Zn deficiency in these soils. A depletion of organic matter in eroded soils causes Zn deficiency. It can also be linked to conditions of weather; morecommon when weather is cold & wet and may be attributed to a lack of root development in cool soils, as well as reduced microbe activity and Zn release from organic materials. Excessive bicarbonate (HCO_3) concentrations inhibit zinc uptake by plant shoots.

Zinc deficiency may also occur on acidic soils which are low in zinc, or on alkaline soils in which the solubility of zinc is reduced. Due to the declining availability of zinc with increasing soil pH, applying lime or dolomite to acid soils may induce zinc deficiency.

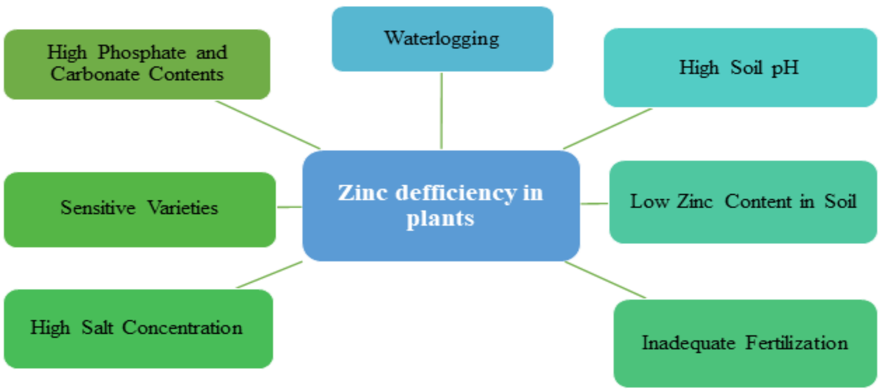


Fig. 1. Factors affecting Zn deficiency

The deficiency of Zn is very common in the wheat-rice cropping system of the sub-continent of Asia. More than 30% soil of the world is under the severe condition of Zn deficiency. Cereals are more vulnerable to the insufficiency of Zn in contrast to legumes which lead to the decrease in grain yield and also its nutritional value. Rice crop is severely affected due to Zn deficiency as compared with other cereals and crops plants.

Sensitivity of different crops to Zn deficiency

Numerous plant species, including, maize, bean, rice, wheat, tomatoes and rice are considered to be less resistant to zinc deficiency and show major crop losses when compared to more tolerant plant species as given in **Table 2** (Xue et al. 2016). The relative susceptibility of different crops to deficiency of zinc varies (Alloway 2008).

Table 2. Sensitivity of different crops to Zn deficiency

Low Sensitive	Medium Sensitive	Highly Sensitive
Asparagus	Alfalfa	Bean
Carrot	Barley	Citrus
Forage grasses	Clover	Cowpea
Mustard	Cotton	Maize
Oat	Sorghum	Millet
Pea	Sugar beet	Onion
Rye	Sugar can	Rice
Wheat	Sunflower	-
Paper mint	-	-

Source: Xue et al. 2016

The Role of Zinc in Plant Nutrition

Zinc is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not present in plant tissue. Carbohydrate, protein, and chlorophyll formation is significantly reduced in zinc-deficient plants. Therefore, a constant and continuous supply of zinc is needed for optimum growth and maximum yield. Role of zinc in plant growth and production is displayed in **Figure 2.**

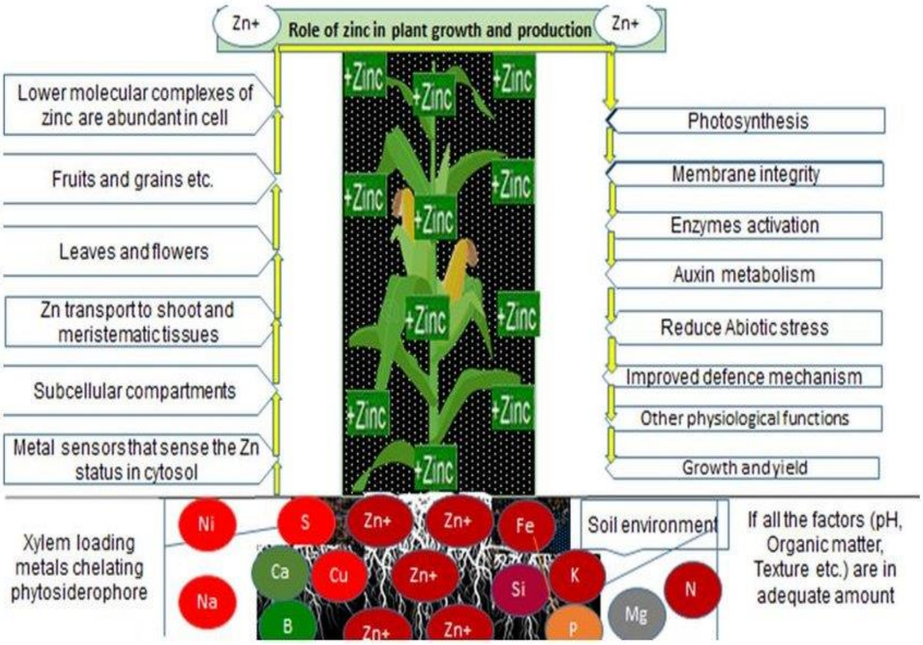


Figure 2. Role of Zinc in plant growth and production

Source: Tayyiba et al (2021)

Deficiency Symptoms

Crop-wise deficiency symptoms are briefly summarised below:

Maize: Maize is the field crop where zinc deficiency is most often observed in India. Zinc deficiency in maize begins as an interveinal chlorosis usually during the 4 to 6 leaf stage have a "rosette" appearance with shortened inter-nodes. As the plants get older and the root system removes zinc from a larger volume of soil, the newer leaves may be normal. When the zinc deficiency is mild (only 1 or 2 leaves per plant are affected and new leaves are normal), little or no yield reduction occurs (**Picture 1**). Under severe conditions (plants stunted and 4 or more leaves show symptoms), silking and tasselling may be delayed 2 to 6 days and barren ears may result. Yield may be reduced by 10 to 30% as a result of zinc deficiency.

Picture 1. Zinc deficiency symptoms in maize

Rice: Zinc deficiency is the most widespread micronutrient disorder in rice. Symptoms appear between two to four weeks after transplanting as dusty brown spots on upper leaves of stunted plants, uneven plant growth and patches of poorly established hills in the field, but the crop may recover without intervention, increased spikelet sterility in rice. chlorotic midribs, particularly near the leaf base of younger leaves, leaves lose turgor and turn brown as brown blotches and streaks appear on lower leaves, enlarge, and coalesce, white line sometimes appears along the leaf midrib, leaf blade size is reduced (**Picture 2**). Symptoms may be more pronounced during early growth stages because of Zn immobilization (due to increased bicarbonate concentration in the soil under strongly reducing conditions following flooding). If the deficiency is not severe, plants can recover after 4−6 weeks, but maturity is delayed and yield reduced.

Picture 2. Zinc deficiency symptoms in rice

Wheat: Zinc deficiency in wheat appears as interveinal chlorosis on the most recently developed leaves; plants are stunted and produce few tillers; if the deficiency is severe the leaves may turn white and die. The most characteristic reactions of wheat plants to zinc deficiency are reductions in plant height and leaf size (**Picture 3**). These symptoms are followed by the development of whitish-brown necrotic spots on middle-aged leaves. As the severity of zinc deficiency intensifies, the necrotic spots spread on the leaves, and the middle parts of the leaves are often collapsed, showing a "**scorched**" appearance.

Picture 3. Zinc deficiency symptoms in wheat

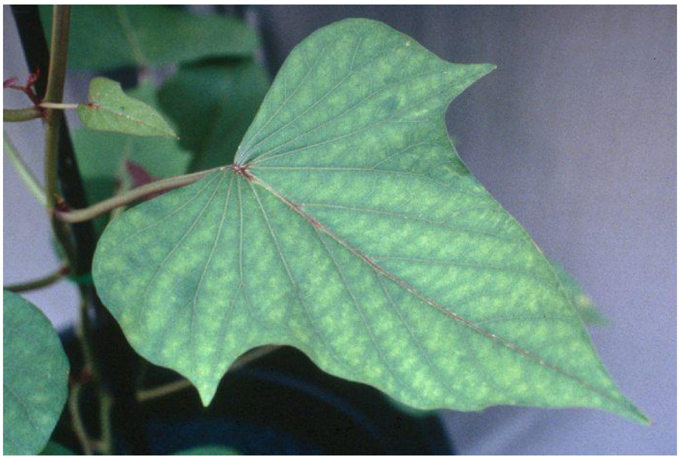
Soybean: Younger leaves of Zn-deficient plants show interveinal chlorosis and necrotic brown leaf veins (**Picture 4**).. The tolerance of Zn deficiency varies strongly between different soybean cultivars.

Picture 4. Zinc deficiency symptoms in Soyabean

Tomato: Deficiency appears first on older leaves in the form of interveinal chlorosis. Inhibit both vegetative growth and fruit production. Shortened internodes, diminutive leaves with under curling of leaflets, epinastic curvature of leaves and chlorosis (**Picture 5**). Oozing out of cell contents as a brown fluid from the leaves.

Picture 5. Zinc deficiency symptoms in tomato

Sweet potato: The most distinctive symptom of zinc deficiency in sweet potato is a reduction in the size of young leaves. The leaves are thickened but usually not distorted, and may be as small as 1-3 cm in length. After the onset of this symptom, plant growth is severely limited (**Picture 6**). It has been reported that the storage roots of zinc-deficient sweet potato plants are of normal shape and size, but may display a brown discolouration of the flesh.



Picture 6. Zinc deficiency symptoms in sweet potato

Potato: Younger leaves show interveinal chlorosis and necrosis which occurs in irregular patches. The characteristic symptom like little leaf is commonly observed. Whitish spots may develop within the brown necrotic tissue. Symptoms may also start on older leaves in case of severe deficiency (**Picture 7**).

Picture 7. Zinc deficiency symptoms in potato

Citrus: Leaves of zinc-deficient citrus are small, abnormally narrow and rather crowded on short stems, giving a bunched appearance Areas between the main lateral veins are whitish yellow. This mottling, which first appears between the main veins, occurs in the young growth and persists as the leaf ages. There is considerable dieback of the smaller twigs, with production of multiple buds and numerous small, weak shoots, so that the trees become bushy and stunted. Leaves of zinc-deficient citrus are small, abnormally narrow and rather crowded on short stems, giving a bunched appearance (**Picture 8**). Fruit tends to be small, rather elongated, pale and coarse.

Figure 8. Zinc deficiency symptoms in potato

Correction of Zinc Deficiency

Soil application of zinc fertilizers is the best method for correcting deficiencies, while foliar application serves as a complementary approach. Several sources can supply zinc when needed. Zinc sulphate monohydrate (33% zinc) is usually used to supply the needed amount of zinc along with NPK fertilizers as basal application. This material can be either broadcast and incorporated before planting. It blends well with other dry fertilizer materials. Approximately 1.5 kg of the zinc sulphate monohydrate material will supply 0.5 kg zinc per acre.

Zinc oxide (78-80% zinc) can correct a zinc deficiency in acid soils but is slowly soluble and not effective in a granular form. To effectively correct a zinc deficiency, zinc oxide must be finely ground.

Organic manures can help correcting zinc deficiency but at slower pace. Application of poultry manure can add considerable amount of zinc to the soil. For example, broiler litter contains 0.01-0.25 kg zinc/ton and laying hen litter contains an average of 0.075 kg zinc/ton. Because zinc content is variable in manure, it is suggested that manure sources be tested for zinc content before application.

The addition of zinc to a starter fertilizer is the most economical approach to zinc fertilization. This method provides the nutrient the year it is needed. This is especially important when corn and edible beans are rotated with other crops. If use of a starter fertilizer is not an option, zinc fertilizers should be broadcast and incorporated before planting of either corn or edible beans.

Foliar applications of zinc have not been consistently effective in correcting deficiencies of this nutrient. For foliar applications, 3-4 grams of zinc sulphate monohydrate can be dissolved in one litre water and applied to the leaf tissue. The amount dissolved should supply 0.25 to 0.5 kg zinc per acre when 100 litres of water per acre is used.

A zinc chelate can also be mixed with water. The amount of chelate mixed with water should supply 0.0.075 kg zinc per acre when water is sprayed at a rate of 100 litres per acre.

Research has shown that all sources of zinc (except granular zinc oxide) have an equal effect on crop production. Consider cost before choosing a source of zinc for the fertilizer program.

Severe Zn deficiency can be corrected with a soil application of 15–20 kg/ha of zinc sulphate monohydrate, worked into the soil well before sowing/transplanting. Zinc is not mobile in the soil and needs to be evenly distributed over the soil surface, and then thoroughly cultivated into the topsoil.

Seed treatments: Zinc seed treatments may be a cost-effective option where soil P levels are adequate but Zn levels are likely to be deficient. To minimise damage to the rhizobia, the Zinc treatment needs to be applied first and then allowed to dry before applying the inoculum.

Foliar feeding: One or two sprays will need to be applied within 6–8 weeks of emergence. Hard water (high in carbonate) will produce an insoluble sediment (zinc carbonate) when the zinc sulphate is dissolved, with the spray mix turning cloudy. Plants often recover as foliar spray of zinc sulphate monohydrate @ 0.3-0.4% twice at fortnightly interval.

Epilogue

Plants, humans, and animals all require zinc for optimum growth and development. Zinc deficiency in soil is an important restriction for the production of crops and a well-known human health issue.

In semi-arid and arid regions of the world, deficiency of zinc is very common due to an increase in fixation and decrease in solubility. In conclusion, correcting zinc deficiencies by fertilizers is not only a way to increase yield, but a way to improve the health and lives of many. To overcome the zinc deficiency there is need to create greater awareness among farmers about the importance of use of zinc in zinc deficient soils with the help of extension workers and educate farmers to diagnose and correct zinc deficiency which would help to increase yields and farmer income while also enhancing nutritional quality of crops and ultimately human nutrition. For higher crop yields, balanced fertilizeruse with zinc is essentially needed.

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ISSN : 2583-0910
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Article ID : 04/IX/38/0924

FEEDING SMART FROM THE RIGHT START

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From the moment your baby arrives, you want to make sure they get the best start in life. One of the biggest ways to do this is by making smart choices about their food. The latest National Family Health Survey (NFHS) shows that India faces a serious problem with child malnutrition. Nearly 36% of children under five are too short for their age because they aren't getting enough to eat. About 21% are too thin for their age, and 11% are dangerously underweight for their height. These figures highlight a major issue with how children are nourished and their overall health. Addressing this problem will need efforts to improve food availability, healthcare, and nutrition for mothers and children.

In 1975, the Academy of Nutrition and Dietetics began National Nutrition Week to encourage healthy eating and exercise. It was so popular that by 1980, it became National Nutrition Month, giving people an entire month to focus on good nutrition and fitness. National Nutrition Week (NNW) in India will be from September 1–7, 2024. Started by the Ministry of Women and Child Development, this week helps people understand why good nutrition is important. The theme for 2024 is "Nutritious Diets for Everyone," which aims to promote healthy diets for all ages and aligns with the goal for sustainable development.

"Feeding smart right from the start" means giving kids healthy food from birth to help them stay healthy and avoid problems later on. By starting good eating habits early, you can help prevent illnesses, reduce the risk of health issues like obesity and diabetes, and ensure they grow up strong and well-nourished. It's all about setting them up for a healthier life from the beginning. When it comes to your child's health, starting good eating habits early can make a big difference. Here's why it's so important and how you can make it easy:

Why Early Nutrition is Important ?

Building a Strong Foundation: Just like a house needs a strong base, your child's body needs good nutrition to grow properly. Starting with healthy foods helps them develop strong bones, muscles, and organs from the very beginning.

Preventing Health Problems: Eating healthy early on can help your child avoid health issues later in life. Good nutrition lowers the chances of problems like obesity, diabetes, and heart disease in the future. It's like setting them up for better health as they grow.

Supporting Growth: Kids grow quickly, especially when they're young. A balanced diet gives them the energy they need to play, learn, and grow. It helps ensure they're developing as they should and reaching important milestones.

Creating Healthy Habits for Life:

Building Good Eating Habits: Children often stick with the eating habits they learn when they're young. By introducing them to healthy foods and making mealtime routines enjoyable, you help them make good food choices throughout their lives.

Making Food Fun: Healthy eating doesn't have to be dull. Get your child involved in picking out fruits and veggies or helping with simple cooking tasks. Making mealtime fun can help them enjoy healthy foods more.

Easy Tips for Healthy Eating:

Start Simple: Begin with easy, nutritious foods like fresh fruits, vegetables, whole grains, and lean meats. These foods provide the essential vitamins and minerals your child needs to grow strong.

Offer a Variety: Keep mealtimes interesting by offering different healthy foods. Try new fruits, veggies, and grains to make sure your child gets a mix of nutrients.

Make Meals Enjoyable: Eat together as a family, avoid distractions like TV or phones, and talk during meals. This helps your child learn that mealtimes are special and makes eating healthy more enjoyable.

Be a Good Example: Children look up to adults. Show them that you enjoy healthy foods and good eating habits. They're likely to follow your lead.

Enjoying the Process: Feeding your child smartly is about more than just following rules—it's about making mealtime fun and meaningful. Celebrate their progress, try new recipes, and enjoy spending time together at the table.

By focusing on good nutrition from the start, you're helping your child have a healthier and happier life. It's one of the best things you can do for their future.

ISSN : 2583-0910
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Article ID : 04/IX/39/0924

REVOLUTIONIZING AQUACULTURE: INTEGRATED BIOFLOC-COPEFLOC AN INNOVATION TECHNOLOGY

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Abstract

Aquaculture has evolved as a cornerstone of global food security, but it faces numerous challenges, including water quality management, disease control, and sustainable feed practices. Biofloc - Copefloc, an innovative technology, merges the principles of biofloc technology with the co-culture of beneficial microorganisms and copepods offering a revolutionary approach to aquaculture. This article delves into the fundamentals of Biofloc -Copefloc, and its potential to enhance water quality, promote fish health, and reduce environmental impact, marking a new era in sustainable aquaculture practices.

Introduction

Aquaculture is a rapidly growing industry, contributing significantly to global food production and economic development. However, aquaculture expansion has brought challenges such as the deterioration of water quality, the spread of diseases, and the sustainability of feed resources. Traditional aquaculture systems often struggle to balance high productivity with environmental responsibility. As a result, innovative approaches are needed to address these issues and pave the way for sustainable aquaculture practices.

One such innovation is Biofloc-Copefloc technology, which builds on the established concept of biofloc technology. Biofloc technology utilizes a mix of organic carbon and nitrogen-rich waste products to promote the growth of beneficial microbial communities. These microorganisms help maintain water quality by converting waste into microbial protein, which the cultured species can consume. Copefloc is the practice of taking cues from nature's problem-solving strategies and using them to improve humankind. This innovative idea has also been used to the shrimp farming industry, where farmers are growing copepods in place of biofloc to boost copepod output. Srijit *et al*., (2018). Copepods are a great natural food source and also function as an immunostimulant to ward off disease. Because of this technology's greater ability to compensate for the lack of need for artificial feed and instead produce natural feed through the use of fermented rice and soy products, prawn farming will undoubtedly change soon. Integrating these Biofloc-Copefloc takes this a step further by incorporating co-cultured beneficial microorganisms with copepods enhancing the system's efficiency and sustainability.

The Biofloc Technology (BFT)

Biofloc-Copefloc integrates two advanced concepts: biofloc technology and the co-culture of beneficial microorganisms with copepods. This dual approach provides a more holistic solution to some of the most pressing issues in aquaculture. “Biofloc Technology” (BFT) could be a potential and sustainable alternative that can reduce environmental impacts with zero water exchange, and less feed input while increasing stocking density and hence the production and crop yield. The technology works on the basic principle of bio-flocculation, where the retention of organic nitrogenous was converted into a proteinaceous compound, which could be utilized by the fish as a natural food source Avnimelech, (2006). BFT has been extensively used for culturing various aquatic species including fish and shrimp where the water exchange is limited and the microbial immobilization of ammonium is required, all of which are essential practices for sustainable aquaculture production Ekasari *et al*., (2015).

The Copefloc Technology (CFT)

The production of copepods in the culture system. The zooplankton copepod lives in fresh, salt, and brackish water all around the world. Due to their short lives of one year, these tiny crustaceans have many uses in nature viz., food for aquatic organisms like shrimp, prawn, fish larvae, nutrient recyclers and convert energy in the food chain (Christenson, 2016). The use of copepods has intensified in the shrimp farming sector, owing to their better biochemical composition (Drillet *et al*., 2006), improvement in survival rate and growth (Rajkumar and Vasagam, 2006), ability to reduce post-mortem mal pigmentation (Shields *et al*., 1999). The new concept via novel technology has been introduced in the shrimp farming sector too where the farmers are building copefloc integrated with biofloc to stimulate the production of crustacean copepods in the system. The perspective, and manner of the Copefloc technique (CFT) are considered as a promising novel technology for the aquaculture system. For the first time, Copefloc is utilized as a novel live food in Thailand's shrimp culture industry's larviculture. (Santhanam *et al*., 2020).

Revolutionizing: Biofloc-Copefloc concept

By integrating biofloc technology, which involves cultivating beneficial microbial communities that consume organic waste and improve water quality, with the culture of copepods, a natural and highly nutritious live feed, Copefloc offers a comprehensive solution. The synergy between these two components not only enhances water quality but also provides a continuous, high-quality feed source that promotes the health and growth of cultured species. This technology is poised to revolutionize aquaculture practices, offering a sustainable, cost-effective, and environmentally friendly alternative to traditional methods. Carbon sources such as rice bran, fermented rice bran, rice flour, sugar, molasses, Tapioca flour, and wheat flour have been used for biofloc development. The growth and stability of the flocs formed can also be determined by using different carbon sources and at various C/N ratios. The Biofloc technique, which maintains the carbon and nitrogen in the culture water, uses dense microbial biomass to extract ammonia and serves as a nutritional supplement.

Method of biofloc -Copefloc production

Natural live copepods are introduced into culture ponds with a 1.2 to 1.5 meters depth, where oxygen is enriched through vigorous aeration for 24 to 48 hours. Rice bran, at a rate of 300 kg per hectare, is fermented with probiotics was inoculated in the pond. Continuous aeration is provided for 7 to 10 days to create a favorable environment for the mass production of live copepods in the pond. The copepod-biofloc inocula solution is prepared by fermenting a mixture of 1 liter of water, 10 grams of cereal (such as fishmeal, soybean meal, groundnut oil cake, wheat bran, tapioca flour, etc.), and 10 mL of a pure cultured strain of probiotic species *Bacillus subtilis* and *Bacillus sphaericus*, with a bacterial density of 10^6 mL^-1. This fermentation process is carried out under optimal conditions of strong aeration for 48 hours, maintaining a pH of 6.0 to 7.2, and adding a buffer pH solution at temperatures ranging from 25 to 28°C. As microorganisms proliferate, large bubbles form on the surface, and a carbon source is added to the pond. (Santhanam *et al*., 2020). The biofloc production leads to the increase of heterotrophic bacterial population and results in floc formation further it will be a food source for various zooplankton like copepods, amphipods, etc.

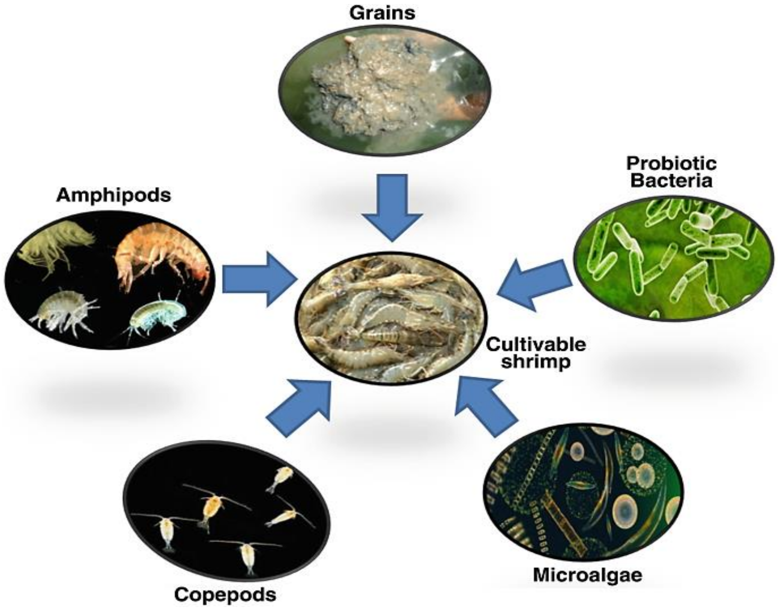

Figure 1: Concept of Biofloc- Cope-floc integration
(Image credit: Santhanam *et al*., 2019)

Significance of Copefloc in Fish and Shrimp Farming

Copefloc is an innovative aquaculture technology that combines the benefits of copepods (small crustaceans) and biofloc systems to create a more sustainable and efficient method for fish and shrimp farming. The significance of Copefloc lies in its ability to enhance the natural feeding process, reduce the need for external feed inputs, and improve water quality. By integrating copepods, which are rich in essential nutrients, into the biofloc system, Copefloc offers a more balanced and nutritious diet for farmed species, leading to healthier growth and improved survival rates. Additionally, this approach supports the reduction of environmental impacts by minimizing waste and optimizing resource use, contributing to the sustainability of aquaculture practices.

Enhanced Water Quality Management

Water quality is a critical factor in aquaculture, directly impacting the health and growth of aquatic species. Biofloc-Copefloc excels in maintaining optimal water quality by fostering a robust microbial ecosystem. The co-culture of specific bacteria and algae enhances the system's ability to break down organic waste, reducing the accumulation of harmful substances like ammonia and nitrites. This creates a healthier environment for fish and shrimp and reduces the frequency of water changes, saving both water and labor.

Improved Fish Health and Growth

Disease outbreaks are a major concern in aquaculture, often leading to significant economic losses. The Biofloc-Copefloc system contributes to improved fish health by enhancing the immune response of the cultured species. The beneficial microorganisms present in the system outcompete pathogenic bacteria, reducing the incidence of diseases. Additionally, the microbial protein generated within the system serves as a nutritious supplement, promoting better growth rates and feed conversion efficiency.

Sustainability and Environmental Impact

One of the standout features of Biofloc-Copefloc technology is its contribution to sustainability. By recycling waste within the system, it minimizes the need for external feed inputs and reduces the environmental footprint of aquaculture operations. The co-cultured microorganisms help in nutrient cycling, ensuring that valuable resources are not lost but reused within the system. This closed-loop approach is key to reducing the dependency on wild fish stocks for feed and mitigating the environmental impact of aquaculture.

Management of Bio-Copefloc Systems

Biofloc-Copefloc management requires careful monitoring and balancing of several key factors to ensure the system's efficiency and sustainability:

Water Quality Management: Regular monitoring of water parameters such as pH, dissolved oxygen, ammonia, nitrite, and nitrate levels is crucial. The biofloc system helps maintain water quality by promoting the growth of beneficial microbes that convert harmful compounds into less toxic forms. Copepods also contribute by consuming excess nutrients and organic matter.

Feed Management: Copefloc systems rely on a mix of natural feed (copepods) and supplementary feed. Proper feed management is essential to prevent overfeeding, which can lead to water quality issues. Farmers must ensure that the copepod population is maintained at optimal levels to provide a consistent food source for the farmed species.

Copepod Cultivation: Cultivating and maintaining a healthy copepod population within the system is crucial. This involves providing the right conditions for copepod reproduction and growth, such as maintaining appropriate salinity, temperature, and light levels. Periodic introduction of new copepod strains may be necessary to maintain genetic diversity and population health.

Biofloc Maintenance: Regular monitoring and control of the biofloc volume are necessary to prevent excessive floc formation, which can negatively impact water quality and farmed species' health. Periodic removal of excess biofloc and water exchange may be required.

Limits concerning biofloc-Copefloc Systems

Complex Management: Copefloc systems require careful and continuous management, including regular monitoring of water quality, copepod populations, and biofloc levels. This complexity may require additional training and expertise for farmers.

Initial Setup Costs: The initial investment for setting up a Copefloc system, including infrastructure for copepod cultivation and biofloc maintenance, can be higher than traditional farming systems.

Risk of System Imbalance: Imbalances in the system, such as overproduction of biofloc or a decline in copepod populations, can lead to poor water quality and negatively impact farmed species' health.

Limited Commercial Application: While Copefloc offers numerous benefits, its commercial application is still limited, and large-scale adoption may require further research and development to optimize the system for different species and environmental conditions.

Maintenance of Copepod Populations: Maintaining a healthy and stable copepod population can be challenging, especially in large-scale operations where environmental fluctuations may impact copepod reproduction and survival.

Conclusion

Biofloc-Copefloc technology represents a significant advancement in the field of aquaculture, offering a comprehensive solution to some of the industry's most critical challenges. By enhancing water quality, improving fish health, and promoting sustainability, this innovative approach paves the way for a more resilient and responsible aquaculture industry. As the global demand for seafood continues to rise, technologies like Biofloc-Copefloc will be essential in ensuring that aquaculture can meet this demand in an environmentally sustainable manner.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/40/0924

RFID TECHNOLOGY: A GAME CHANGER FOR MODERN FARMING EFFICIENCY

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Introduction

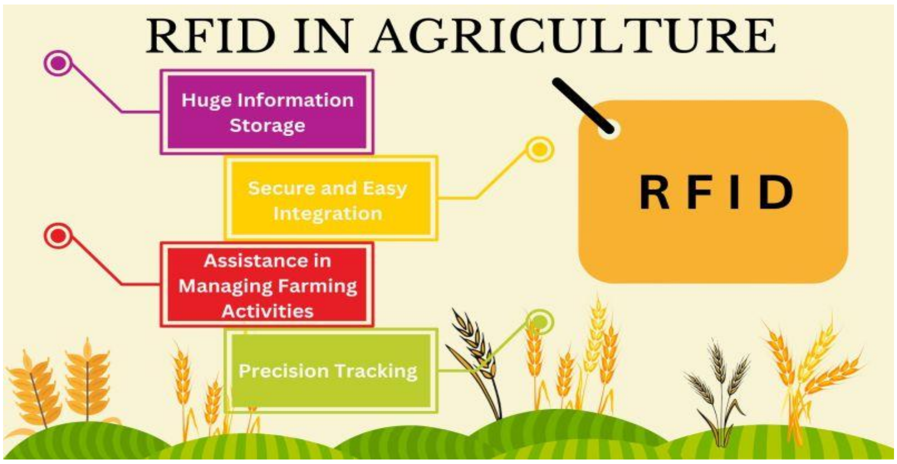
RFID technology offers significant advantages for farmers throughout the cultivation process, playing a crucial role in modern agriculture. Its application spans various facets of the sector, including real-time monitoring and data collection, which can greatly enhance harvest success. Recent advancements in RFID have unveiled promising possibilities for agricultural practices. By using radio waves to read and write data on RF tags, RFID facilitates animal tracking in livestock farming and traceability in processed food chains. Compared to data loggers and barcodes, RFID provides superior efficiency by delivering accurate, real-time information without requiring visual contact or direct interaction.

Radio Frequency Identification (RFID) operates through radio waves to wirelessly identify and track objects or individuals. It consists of two primary components:

- **RFID Tag**: A small electronic device that stores a unique identifier and additional data.
- **RFID Reader**: A device that emits radio waves and captures signals from RFID tags within its range.

RFID technology is widely utilized in various commercial and industrial applications, such as tracking items along a supply chain or managing inventory in warehouses.

In agriculture, RFID technology enhances efficiency by monitoring and managing crop and livestock health, as well as ensuring the safe packing and transportation of agricultural products. With specialized hardware and software, RFID provides a comprehensive and cost-effective monitoring system, offering considerable benefits to farmers by improving productivity and operational efficiency.

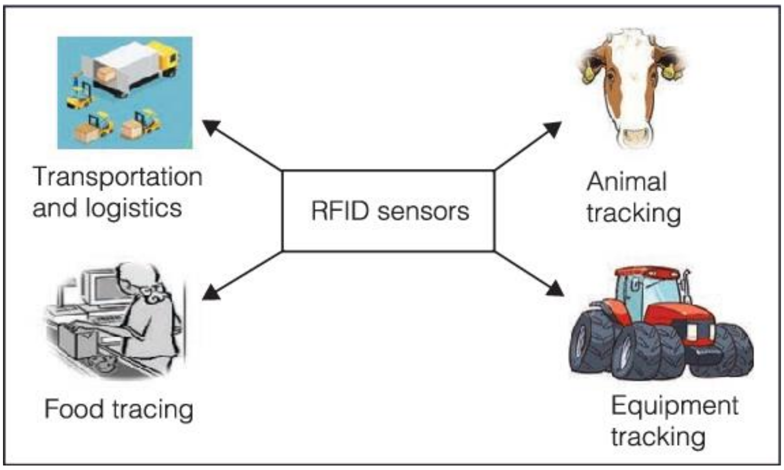


Source: https://www.linkedin.com/posts/dehaat_rfid-technology-agritech-activity

Benefits of RFID Technology in Agriculture

RFID technology offers numerous advantages in agriculture, enhancing efficiency and production by streamlining various operations. It enables stakeholders to closely track and monitor agricultural commodities.

- **Comprehensive Data Storage**: RFID tags can store extensive information about crops, such as harvest dates, moisture levels, temperatures, and nutritional content, ensuring accurate data availability at all times.
- **Enhanced Security and Integration**: These tags are secure and can be seamlessly integrated into existing systems.
- **Smart Greenhouse Integration**: In smart greenhouses, RFID technology gathers essential data that aids in managing equipment, optimizing resource use, and monitoring crop development and harvesting schedules.
- **Food Safety and Traceability**: RFID facilitates the tracing of agricultural products from production to the consumer, supporting food safety throughout the entire distribution process.
- **Streamlined Export and Import**: The technology automates the storage and retrieval of information during the export and import of agricultural goods, simplifying logistics and improving accuracy.



Source:https://www.semanticscholar.org/paper/RFID-Sensing-Technologies-for-Smart-Agriculture

RFID in Farming and Agriculture: Enhancing Global Food Production

The integration of RFID technology in agriculture is transforming global food production by boosting efficiency, minimizing waste, and ensuring high product quality. Here's how RFID is impacting various aspects of agriculture:

1. **Automating Farm Operations** RFID technology, combined with IoT sensors and network systems, is crucial for automating agricultural tasks. By tagging crops and livestock, farmers can monitor every phase of cultivation, harvesting, and distribution. This automation reduces labor costs, facilitates real-time monitoring, and allows for prompt interventions. The data collected improves yield management and helps identify potential issues early, leading to more controlled and efficient farming practices.
2. **Enhancing Climate Data Management** RFID tags linked to computer networks enable farmers to track and respond to climate changes effectively. This capability is essential for

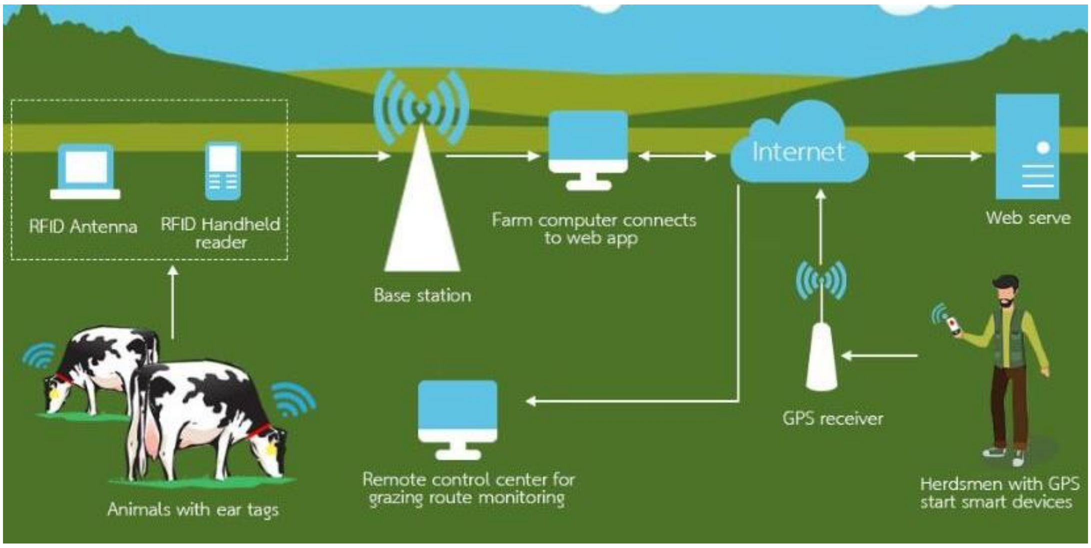
maintaining optimal growing conditions and ensuring freshness during transportation and storage. By recording climate information, farmers can make informed decisions, manage inventories accurately, and forecast crop yields. RFID in transport vehicles also ensures that produce is monitored throughout the supply chain, supporting timely delivery of fresh products.

3. **Boosting Agricultural Productivity** RFID technology improves farm productivity by automating the collection of crop data and inspections. This reduces the need for manual labor in monitoring and managing crops. With RFID tags, farmers can efficiently respond to changing conditions and make data-driven decisions, leading to higher yields and better crop management.
4. **Monitoring Livestock Health** RFID tags are essential for managing livestock by enabling real-time health monitoring and traceability. They assist in detecting and managing diseases, ensuring compliance with health regulations. Automated systems can perform livestock inspections and send data to regulatory bodies, enhancing herd health. In the event of disease outbreaks, RFID technology facilitates quick isolation and management of affected animals, minimizing the impact on the herd.
5. **Providing Consumer Transparency** RFID technology enhances transparency in the food production process, allowing consumers to trace the origin and journey of their food. This transparency builds consumer trust and meets the increasing demand for information on farming practices, environmental conditions, and pesticide use. By certifying each production stage, farmers can assure consumers of the safety and sustainability of their products, giving them a competitive market advantage.

RFID in Cattle Tracking

1. **Individual Animal Identification**
   - RFID tags are used on each animal, often as ear tags or implants.
   - Unique identifiers track data such as age, breed, health status, and vaccination records.
2. **Health Monitoring**
   - RFID tags, integrated with sensors, monitor vital signs and detect early illness signs.
   - Real-time health data collection enables prompt interventions and reduces disease risk.
3. **Breeding Management**
   - RFID technology tracks reproductive cycles and manages breeding programs.
   - Accurate records of estrus cycles, mating, and pregnancy improve breeding success.
4. **Movement Tracking**
   - RFID systems monitor cattle movement within farms or during transportation.
   - This aids in managing grazing patterns, ensuring animal safety, and optimizing pasture use.
5. **Regulatory Compliance**
   - RFID tags help maintain records for regulatory compliance.
   - Detailed tracking data supports adherence to animal welfare standards and export requirements.
6. **Feed Management**
   - RFID technology monitors and controls individual feeding regimens.

- Ensures each animal receives the correct feed type and amount, optimizing growth and health.



Source: https://www.linkedin.com/pulse/rfid-tag-animal-tracking-identification

RFID in Agriculture Equipment Tracking

1. Asset Management:

- RFID tags attached to equipment such as tractors, harvesters, and irrigation systems help in tracking their location and usage.
- Real-time data on equipment whereabouts prevents loss and theft.

2. Maintenance Scheduling:

- RFID systems can log usage hours and trigger maintenance schedules based on actual usage data.
- Ensures timely maintenance, reducing downtime and extending equipment life.

3. Utilization Monitoring:

- Data collected from RFID tags helps in analyzing equipment utilization rates.
- Identifies underused or overused equipment, optimizing resource allocation.

4. Operational Efficiency:

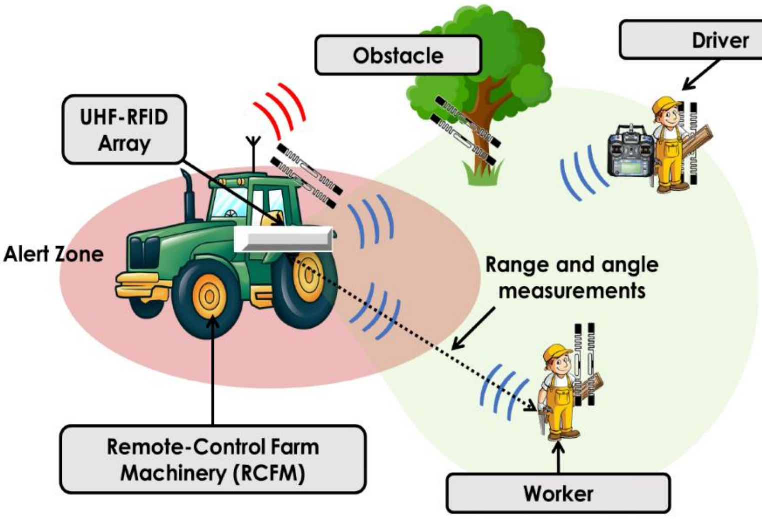
- RFID technology streamlines equipment check-in and check-out processes.
- Reduces manual paperwork and errors, improving overall operational efficiency.

5. Inventory Management:

- RFID tags can be used to track spare parts and consumables.
- Ensures that necessary parts are available when needed, reducing delays and improving repair times.

6. Precision Farming:

- RFID technology integrates with GPS and other systems to enhance precision farming techniques.
- Enables accurate field mapping, planting, fertilizing, and harvesting operations, leading to better crop yields.



Source: https://doi.org/10.3390/electronics11050717

Challenges of Using RFID Technology in Agriculture

While RFID technology offers many benefits, it also presents several challenges that need to be addressed:

- **Performance in Adverse Weather**: RFID systems may struggle in extreme weather conditions such as very high or low temperatures and heavy rain. For optimal operation, stable weather conditions are often required.
- **Data Management**: RFID tags can store substantial amounts of data, necessitating effective data management systems. Without proper data management, the information collected may not be utilized effectively.
- **Signal Interference**: The effectiveness of RFID systems can be compromised by physical obstructions such as dense crop canopies, which can affect signal strength and reading range. Solutions are needed to improve signal penetration and reliability.
- **Frequency Compatibility**: Since RFID operates on various radio frequencies, understanding and selecting the appropriate frequency for different applications is essential for maximizing system efficiency and data accuracy.
- **Cost Considerations**: The initial investment in RFID technology can be high, which might be a barrier for some farmers. However, the long-term benefits can outweigh the short-term costs.

Conclusion

RFID technology can be an essential tool for farmers, aiding in the monitoring and tracking of agricultural commodities to prevent potential issues. However, effective implementation requires proper training for farmers to operate the systems efficiently. Training programs are crucial for farmers to make the most of RFID technology. Organizations like DeHaat provide valuable on-the-ground support and training to help farmers adapt to new technologies. DeHaat’s commitment to the principle of "Farmers First" drives its efforts to enhance farmers' livelihoods and address their needs comprehensively.

Article ID : 04/IX/41/0924

SEA AMBULANCE - A MESSIAH FOR COASTAL FISHERS

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Abstract
The article summarizes the concept, history, and current status of sea ambulances worldwide, with a focus on recent developments and initiatives in various countries, including Japan, Dubai, Sweden, the United Kingdom, Italy, Tanzania, Thailand, Australia, the United States, and India. It highlights that maritime ambulances have developed from makeshift fixes to advanced, modern ships with specialized medical supplies and highly skilled crew. The article also delves into the efforts made by Indian Central and State Government agencies to provide medical aid to fishers while at sea.

Keywords : Coastal guard, Maritime, Rescue, Sea ambulance

Introduction
A sea ambulance, also known as a marine ambulance or an ambulance boat, is a particular kind of boat that is equipped to provide emergency medical attention and transfer to individuals in offshore or coastal areas. Where access for land-based ambulances is either limited or non-existent, Sea ambulances are designed to transport patients across bodies of water. These boats are equipped with life-saving equipment, oxygen, basic first aid kits, defibrillators, and other medical supplies to keep patients stable during travel. Emergency medical technicians (EMTs) or paramedics who have completed medical training are typically qualified to staff sea ambulances and provide care while they are in transit. They have navigational and communication systems set up to ensure efficient and secure water transportation. In the pre-modern era, records suggest makeshift solutions existed. Fishing communities would convert boats for rescue operations in emergencies. However, dedicated medical equipment and trained personnel were likely absent. In the 19^{th} Century, Lifeboats evolved with improved designs and rescue capabilities. They served a dual purpose, saving lives from immediate danger and offering basic first aid until reaching land based medical care. In the 20^{th} Century, technological advancements spurred dedicated marine ambulance services. Motorized boats equipped with basic medical supplies and trained personnel started appearing particularly in coastal communities reliant on maritime activities. At the time of World War II, Amphibious operations and naval warfare highlighted the need for efficient medical evacuation at sea. Dedicated military "hospital ships" and smaller landing craft adapted for medical transport emerged. Civilian marine ambulance services continued to develop, primarily in areas with extensive waterways, islands, or offshore industries like fishing and oil rigs. Modern marine ambulances vary depending on their target population and environment. Some cater to recreational boaters, others serve offshore industries, and specialized units handle underwater emergencies like scuba diving accidents. Today's marine ambulances boast communication systems, GPS navigation, specialized medical equipment, and trained paramedics able to provide advanced life support.

Sea ambulance service around the world

Figure 1: Japan marine ambulance

Source: https://www.ph.emb-japan.go.jp/itpr_en/11_000001_00020.html

The Tokyo Fire Department launched a specialist water ambulance service in Japan in 1931, complete with medical staff and a specialized boat. Rescues and medical emergencies in the city's harbor and nearby waterways were the main uses for this service. Japan boasts a sophisticated marine ambulance network, complete with specialized boats and skilled workers stationed around the country's coastline. Search and rescue, disaster response, and medical evacuations are just a few of the uses for these services. Marine ambulances have a long history in Japan, especially in isolated island villages. These boats frequently have paramedics on staff with extensive medical training and equipment. The sea ambulance service started throughout the world is listed in Table-1.

Table: 1 Sea ambulance services initiative around the world

S. NO	Year	Country	Service Provider
1	1931	Japan	Tokyo Fire Department.
2	1950	United States	United States Coast Guard.
3	1960	Australia	Royal Australian Navy's and Volunteer Coast Guard Association.
4	1973	Italy-Venice	Servizio Urgenza Emergenza Medica (SUEM) Venetian Emergency Medical Service.
5	2003	United Kingdom	Maritime Search and Rescue and South-Western Ambulance Service.
6	2008	Sweden	Sweden Maritime Administration.
7	2015	Dubai	Dubai Ambulance Foundation.
8	2017	India	State Government of Kerala.
9	2019	Thailand	Ruamkatanyu Foundation and Koh Lanta Rescue Foundation.
10	2023	Tanzania	Tanzania Shipping Agency Corporation (TASAC) and United Nations Population Fund (UNFPA).
11	2023	El Salvador	El Salvador Emergency Medical Services (SEM)

Sea ambulance in India:

The Kerala Government launched the country's first marine ambulance, Pratheeksha. The crew was supplied by Kerala Shipping and Inland Navigation Corporation, and the safety team is made up of experienced fishermen. The building of three vessels is part of the marine ambulance initiative. There will be a float-out ceremony for two additional boats, Prathyasha and Karanya. J Mercy Kutty Amma, the minister of fisheries, stated that the boats will be put into service right now. In 2017, Hurricane Ockhi claimed multiple lives, which gave rise to the naval ambulance project. Bharat Petroleum Corporation Limited Donated H 6 crore and CSL H 2.8 crore in addition to government financing. The Cochin Shipyard Limited (CSL) built marine ambulance will be put to use. Pinarayi Vijayan, the chief minister, will give the event its opening. The 6.08 crore ambulance that was constructed would aid in the rescue of fishermen involved in maritime accidents. The fisheries agency estimates that every year, over thirty fishermen perish in various maritime mishaps. The dimensions of the vessel are 23 meters long, 5.5 meters wide, and 3 meters deep. Utilizing a pair of 700 horsepower Scania engines, its top speed is 14 nautical miles per hour. The Central Institute of Fisheries Technology created the boat in accordance with Indian Registry of Shipping requirements. The Cochin Shipyard was given the task of producing three maritime ambulances in the first phase. The project will cost a total of 18.24 crore, or 6.08 crore per boat. The Central Institute of Fisheries Technology (CIFT), located in Kochi, offers technical guidance in building boats.

Figure 2: Kerala marine ambulance

Source:https://www.thehindu.com/news/cities/Kochi/two-mordern-marine-ambulances-launched/article33688904.ece/amp/

Sea ambulance in other states of India

The Chief Minister of Karnataka declared in the State budget 2024-2025 that the first marine ambulance service in the state would be launched to rescue fishermen in an emergency in the case of accidents or medical crises. At a cost of Rs 7 crore, Karnataka will launch its first marine ambulance. For medical situations at sea, call the Indian Coast Guard, which is active along the whole Indian coastline. They have first aid kits on board, basic medical supplies on board, and skilled medics on board who can stabilize patients until they can be sent ashore for additional care. State Fisheries Departments have boats that can be used for medical evacuations at sea, including those in Maharashtra and Tamil Nadu. These, however, may not be easily accessible to the general public as they are primarily intended for use by fishers.

Conclusion

In conclusion, sea ambulances play a crucial role in providing emergency medical care and transportation in coastal and offshore regions. The concept has evolved from makeshift solutions in pre-modern times to dedicated services with advanced technology in the modern era. Various countries, including Japan, Dubai, Sweden, the United Kingdom, Italy, Tanzania, Thailand, Australia, and the United States, have implemented marine ambulance initiatives to enhance emergency medical response on water. India has also embraced the concept, with Kerala launching its first marine ambulance, Pratheeksha, and other states utilizing resources such as the Indian Coast Guard and state fisheries departments for medical emergencies at sea. Overall, sea ambulances continue to be vital in ensuring timely and effective medical care in challenging maritime environments.

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This is the Star of Life, an ambulance boat used around the Isles of Scilly | UK Emergency Vehicles"(UKEMERGENCY,2011)

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ISSN : 2583-0910
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Article ID : 04/IX/42/0924

SEAWEED SOLUTIONS: HARNESSING OCEAN'S GREEN GOLD FOR HUMAN WELFARE

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ABSTRACT

Seaweeds are chlorophyll-containing organisms that belong to the macroalgae and grow in maritime environments. In many maritime nations, seaweeds are employed as a food source, in industrial processes, and as fertilizer. Seaweeds contain chemicals with possible nutritional advantages in addition to the polysaccharide extractives "alginate, carrageenan, and agar" that have historically been exploited by the Western food industry. These ingredients from seaweed must adhere to industry standards, technological requirements, and consumer safety laws. It serves as a fertilizer, an animal feed additive, and a component in the worldwide food and cosmetics sectors. In many nations nowadays, seaweeds represent a significant coastal resource that is beneficial for both human consumption and the environment. This article aims to address the uses of seaweeds and its benefits associated with human welfare.

INTRODUCTION

Seaweeds are marine algae found in oceans and seas. Seaweeds are traditionally divided into 3 groups: red algae (Rhodophyta), green algae (Chlorophyta) and brown algae (Phaeophyceae) exhibit a variety of morphologies such as wide leaves, spheres, delicate fingers, or fruit-like shapes. The principal components of the cell walls of seaweeds are ulvan for green, agaran and carrageenan for red alginates, and fucan for brown and laminarian as a storage polysaccharide. The chlorophyll content of seaweed is responsible for their color; green algae contain chlorophyll a and b in equal amounts, the same as higher plants, which is responsible for their green color. Brown algae's color is due to xanthophyll and fucoxanthin pigments; they are accessory pigments that hide chlorophylls and other xanthophylls, whereas red algae's color is due to phycoerythrin and phycocyanin pigments, which cover the impact of other pigments and provide its red color. Brown seaweeds are located in temperate waters, while green and red seaweeds flourish completely in tropical waters.

Worldwide, there are around 4000 species of red seaweed, around 1500 species of brown seaweed, and around 900 species of green seaweed available. The Indian coastline is around 8118 kilometers long, with a 2.17 million-square-kilometer EEZ, with its various coastal habitats, accounting for about 271 genera and 1153 seaweed species in the Indian seas (Magdoom *et al*., 2010). Seaweed is a new renewable source of food, energy, chemicals, and pharmaceuticals. Seaweeds contain up to 85% water in their bodies, whereas the others are mostly composed of organic matter and minerals.

Seaweeds are considered to be the ultimate source of bioactive compounds that have been used in nutraceuticals and functional foods. It contains pigments like chlorophylls, fucoxanthin and phycobilin, polyphenols, and mycosporine-like amino acids, which exhibit antioxidant and anti-inflammatory properties. Seaweeds and their products are specifically short in calories and also have chelated micro-minerals like selenium, chromium, nickel, and arsenic. It has a potential against many degenerative diseases. Seaweed bioactive substances are also used in the biomedical and pharmaceutical sectors as they exhibit antitumoral action against some cancer cell lines. Phycocolloids, which are derived from red and brown algae, are utilized in the food sector (gelling agents), medicines (dressings, pharmaceutical coatings), and biotechnology (culture medium, Petri dishes). It can also be employed in cosmetics (such as soaps, body lotions, toothpaste, and shampoos). Marine algae have traditionally been employed in animal feed, agriculture, and biodiesel manufacturing.

SEAWEED USES AND ITS APPLICATION TO HUMAN WELFARE

Seaweed as food

Many maritime nations, notably in Asia, such as Japan, China, and Korea use seaweeds for food, industrial purposes, and fertilizer. Seaweeds are being used in human diets, cosmetics, and the extraction of industrial gums and chemicals. Kombu and kunbu in Chinese (a typical low-cost but high-nutritional-value food item) are used in the production of soups, meat meals, and as a vegetable with rice. Some seaweed has high levels of protein, glucose, and vitamins A, B, B2, and C. Aside from these, there are several trace elements and minerals, the most notable of which is iodine. Another advantage is that it is minimal in calories and hence ideal for all types of vegetarians. Many nations, including Japan, China, Korea, Malaysia, Thailand, Indonesia, the Philippines, and others in Southeast Asia, employ seaweed as a beauty enhancer due to its high protein content. To make soup, salad, and curry, various seaweeds are used such as *Ulva* sp., *Caulerpa* sp., *Macrocystis* sp., *Enteromorpha* sp., *Monostroma* sp., *Codium* sp., *Laminaria* sp., *Sargassum* sp., *Undaria* sp., *Hydroclathrus* sp., *Gracilaria* sp., *Eucheuma* sp., *Porphyra* sp., *Laurencia* sp. and *Acanthophora* sp. Some seaweeds are also consumed in dried form.

Seaweed as functional food

Functional foods are those that provide health benefits beyond basic nutrition, such as fortified products with omega-3 polyunsaturated fatty acids and beverages containing bioactive peptides. Because of their higher calcium concentration and easier absorption (in the form of calcium carbonate) into the body compared to calcium in cow's milk (in the form of calcium phosphate), seaweeds are also rich sources of calcium, which gives them a greater potential to be used in functional food developments. Additionally, seaweeds are beneficial sources of vitamins including vitamins E, A, and B12, and have a larger opportunity to be utilized in functional food categories that are in demand. Nowadays, seaweeds with high-value lipids promise alternate sources of PUFAs, and functional food products fortified with -3 LCPUFAs are extensively consumed.

Medicinal and pharmacological properties

Apart from the nutritional support it has also been used as a various agent like antiviral, antimicrobial, anticancer, antiallergic, antifungal, anticoagulant, antioxidant, and also for antifouling activities. Seaweeds have also been implicated as a potential protective agent against cardiovascular diseases. Yuvaraj and Arul (2014), described the marine brown alga i.e., *Sargassum wightii* as having anti-inflammatory, antioxidant, anti-tumor, and antibacterial activities. Moreover, seaweeds have good antioxidant properties, which play a vital role in fighting against various diseases like cancer, atherosclerosis, chronic inflammation, and cardiovascular disorder, and aging processes. It also prevents the rate of cancer cell formation. Generally, seaweed showed the highest antibacterial activity against different pathogenic microbes such as *Streptococcus pyogenes*, *Bacillus cereus, Klebsiella pneumoniae, Staphylococcus aureus*, *Bacillus subtilis*, *Streptococcus epidermis* and

Enterobacter aerogenes. *Sargassum wightii, Gracilaria corticata,* and *Turbinaria ornate* also have good sources of antimicrobial agents. Dietary intake of seaweed can lower plasma cholesterol and reduce the risk of cardiovascular diseases. Seaweed antioxidants also possess anti-aging properties. The consumption of seaweed triggers various biochemical changes in humans, such as antioxygenic activity, inhibition of cell adhesion, binding toxic compounds, induction of apoptosis, and the addition of essential trace minerals to the diet that mainly aid in preventing chronic diseases and reducing aging in humans.

Anti-obesity effect of seaweed

Obesity, type 2 diabetes, metabolic syndrome, and chronic inflammatory diseases are global epidemics. The World Health Organization estimated that 2.3 billion people were overweight and 700 million were obese by 2015. Brown seaweed lipids have been shown to have several health-related qualities, including antidiabetic and anti-obesity effects. Natural, bioactive, functional compounds like fucoxanthin are being studied to prevent and treat these diseases as an alternative or combination therapy with orthodox medicines. In obesity treatment, fucoxanthin induces uncoupling protein-1 in abdominal adipose tissue mitochondria in murine studies, leading to fatty acid oxidation and heat production, resulting in reduced white adipose tissue.

Seaweed as an anti-oxidant agent

Seaweeds contain various phenolics with antioxidant activities. Flavonoids include anthocyanidins, flavones, flavonols, flavanols, isoflavones, and flavanones. Brown seaweeds have phlorotannins, which may contain novel pharmacological activities. High antioxidant activity phlorotannins were extracted from the brown seaweed *Cystoseira trinodis* and other *Fucales* species. Some species of brown seaweed contain phlorotannins, including eckol, phlorofucofuroeckol, 6,6-beckon, and dieckol. Eckol, found in *Ecklonia sp*. of the Laminariaceae family, has been shown to have scavenging activity on lung fibroblast cells.

Seaweed as anti-diabetic agents

Fucosterol and fucoxanthin are found in brown seaweeds. According to Fernandos *et al*. (2016), fucosterol provides several health advantages, including antidiabetic action (via inhibiting aldose reductase). Omega-3 PUFAs upregulate fucoxanthin activity, which shows antidiabetic activity through two mechanisms. One is the upregulation of glucose transporter type 4 (GLUT4) expression translocation, and the other involves insulin resistance by downregulating tumor necrosis factor-alpha (TNF-), monocyte chemoattractant protein-1 (MCP-1), and interleukin-6 (IL-6).

Seaweeds as anticancer agents

Seaweed consumption has also been linked to a possible preventive factor in the etiology of breast cancer. Brown algae (*Fucus* spp.) has been proven to be effective against colorectal and breast cancers. Moussavou *et al*. (2014) thoroughly established the anticancer impact of several seaweeds on human colon and breast cancers. Ghislain *et al*. documented the anticancer effects of different seaweeds against colon and breast cancer in humans. Different types of seaweeds have shown a protective effect against cancer by reducing or destroying cancer cell formation. The high antioxidant activity of seaweeds plays a major role in reducing the rate of cancer cell formation. *Laminaria* sp. was employed in the treatment of cancer in ancient China, and it is also mentioned in ancient Ayurvedic scriptures. Seaweed in the diet has been shown to reduce the incidence of breast cancer and other types of cancer.

CONCLUSION

Seaweeds offer valuable raw materials for industries such as health food, pharmaceuticals, textiles, fertilizers, and animal feed. With around 844 seaweed species reported in Indian seas, the standing stock is estimated to be about 58,715 tonnes. Even though we have so many seaweed resources, they are still underutilized in food applications. So, utilization of seaweeds as a food source helps in providing various bioactive properties like anti-cancer, anti-oxidant, anti-obesity, anti-diabetic properties which helps in enhancing human health.

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ISSN : 2583-0910
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Article ID : 04/IX/43/0924

SEAWEED-BASED NUTRICOSMETICS: BRIDGING THE GAP BETWEEN NUTRITION AND COSMETICS FOR RADIANT SKIN

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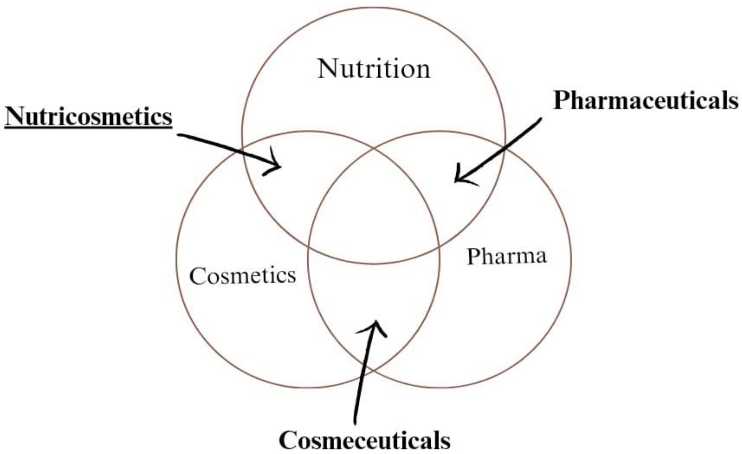
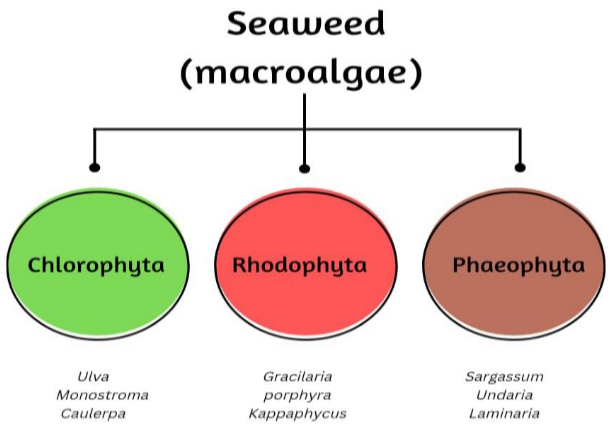
INTRODUCTION

Nutricosmetics are specific macro and micro nutrients that are orally delivered to help provide positive changes in quality of skin and general appearance. Dietary intake has clear connections with skin health and can even limit UV-induced damage. The global market value of natural and organic skincare products will probably grow from 9.9 billion dollars in 2021 to 20.4 billion dollars by 2030. Seaweed is packed with vitamins, minerals, amino acids, and bioactive compounds that support skin health and overall wellness. They are renewable resource that can be harvested sustainably, making it an eco-friendly ingredient for nutricosmetics. Additionally, utilizing waste seaweed contributes to environmental restoration. Marine-derived seaweed compounds offer unique advantages over terrestrial ones in nutricosmetics. Marine environments are rich in bioactive substances not found in terrestrial plants, including antioxidants, anti-inflammatory agents, and UV protectants like mycosporine-like amino acids and astaxanthin. Marine resources can be sustainably harvested, reducing environmental impact compared to some terrestrial farming practices.



SEAWEEDS-AN OVERVIEW

Seaweeds or macroalgae, encompass thousands of species of multicellular marine algae, including red (Rhodophyta), brown (Phaeophyta), and green (Chlorophyta) varieties. They play crucial ecological roles, providing habitats for marine life and contributing to carbon capture and oxygen production. Seaweeds are also rich in nutrients, offering dietary benefits and bioactive compounds with antioxidant and anti-inflammatory properties. They are utilized in food, pharmaceuticals, Nutraceuticals, cosmeceuticals and in the emerging sector nutricosmetics making them valuable for both health and industry.



BIOACTIVE COMPOUNDS FROM SEAWEEDS

Polysaccharides

Marine macroalgae are rich in carbohydrates, primarily polysaccharides, which can range from 5% to 75% of their dry weight, depending on various factors. These polysaccharides can be classified as sulfated or non-sulfated and are essential for cell wall structure.

Brown Algae: Composed mainly of sulfated α-L-fucans, they exhibit antioxidant and antibacterial properties. Fucoidans promote skin health and prevent photoaging.

Red Algae: Feature water-soluble sulfated galactans like agar and carrageenans, widely used in food and cosmetics.

Green Algae: Contain sulfated polyholosides, such as ulvans, utilized for gelling and anti-aging effects.

Lipids

Algae are a source of omega-3 and omega-6 polyunsaturated fatty acids (PUFAs), with γ-linolenic acid, eicosapentaenoic acid (EPA), arachidonic acid, and docosahexaenoic acid (DHA) being the most prevalent. Phaeophyta algae exhibit a C18-PUFAs profile similar to green algae and a C20-PUFAs profile akin to red algae. Green algae, particularly Chlorophyta, have higher DHA levels, while Rhodophyta are richer in C20-PUFAs. These PUFAs enhance skin barrier function and modulate inflammation, while lipids in cosmetics can serve as moisturizers, emollients, surfactants, and emulsifiers.

Proteins

Seaweeds are abundant in proteins and protein derivatives, with red algae containing the highest levels (up to 47%), followed by green algae (9–26%) and brown algae (3–15%). These proteins and bioactive peptides exhibit significant antioxidant, anti-inflammatory, and anti-aging properties. Environmental factors influence the content of proteins and amino acids in algae. Taurine from certain algae has antioxidant properties, while specific peptides from *Porphyra yezoensis* enhance collagen and elastin synthesis. Mycosporine-like amino acids (MAAs) protect against UV radiation and possess various health benefits, including antioxidant and anti-aging effects, making them valuable in cosmetics and personal care products.

Phenolics

- Phenolic compounds are secondary metabolites characterized by one or more aromatic rings with hydroxyl (-OH) groups, including phlorotannins, bromophenols, flavonoids, and mycosporine-like amino acids. They help protect algae from environmental stress and parasites.

- Phlorotannins, found exclusively in brown algae, exhibit strong antioxidant properties, inhibit melanin production, and reduce UV damage. They also possess anti-inflammatory and anti-aging effects, with antioxidant potency surpassing that of ascorbic acid. Bromophenols, present in various algae, display antioxidant, antimicrobial, and anti-inflammatory activities, while flavonoids derived from algae contribute to health benefits through their high scavenging potential.

Terpenoids and sterols

- Terpenoids act as antioxidants, anti-aging agents, anti-inflammatories, skin whitening compounds, antibacterials, and anti-acne agents.
- Meroterpenoids from brown algae like *Sargassum muticum* have antioxidant and anti-photoaging effects.
- Monoterpenoids such as loliolide promote hair growth via AKT-mediated WNT signaling and provide skin whitening benefits.
- Sesquiterpenoids and diterpenoids from red algae display anti-inflammatory properties.
- Phenolic terpenoids, found in red and brown seaweeds, demonstrate anti-inflammatory and antioxidant activities.
- Sterols, present as free forms or conjugates, regulate membrane permeability and fluidity, and possess antioxidant, anti-inflammatory, and photoprotective effects.

Pigments

Algal pigments include brown (carotenes and xanthophylls), green (chlorophylls), and red (phycobilins).

- **Carotenoids**: These lipophilic compounds, such as β-carotene, astaxanthin, and fucoxanthin, serve as natural color enhancers and possess antioxidant, anti-inflammatory, and anti-aging properties. Fucoxanthin can also boost fat burning, while zeaxanthin helps control melanin production.
- **Chlorophylls**: Featuring a porphyrin ring with magnesium, chlorophylls protect against UV-induced oxidative stress. Their derivatives also exhibit antioxidant effects.
- **Phycobiliproteins**: Found mainly in red algae, these proteins have antioxidant, anti-aging, and immune-modulating properties, making them suitable for cosmetic applications.

MECHANISM OF ACTION

Moisturizing effects of seaweed

Seaweed metabolites play a significant role in moisturizing formulations due to their ability to enhance skin hydration and barrier function. The Natural Moisturizing Factors (NMF) in the stratum corneum, including lactic acid and amino acids, facilitate water retention. Algal polysaccharides, particularly from green and brown algae, outperform glycerin in moisture retention. Additionally, unsaturated fatty acids from brown macroalgae, like *Laminaria ochroleuca*, and sulfated polysaccharides from red algae improve skin hydration and integrity. Carotenoids, such as astaxanthin, enhance aquaporin levels, further promoting moisture absorption in the skin.

Anti-aging effects

During aging, the dermis undergoes changes, with increased matrix metalloproteinases (MMPs) activity and reduced collagen levels. Both intrinsic and extrinsic factors contribute to skin issues like

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dryness, wrinkles, and enlarged pores. Bioactive compounds from algae, such as sulfated polysaccharides, polyphenols, and fucoidan, inhibit MMPs and support skin function. Carrageenans provide thickening and antioxidant properties, while galactan from Phaeophyceae regulates cellular aging. Carotenoids like astaxanthin protect against photo-oxidation, and fucoxanthin boosts procollagen synthesis. Additionally, amino acids and peptides from macroalgae stimulate collagen production and combat oxidative stress.

Skin whitening effects

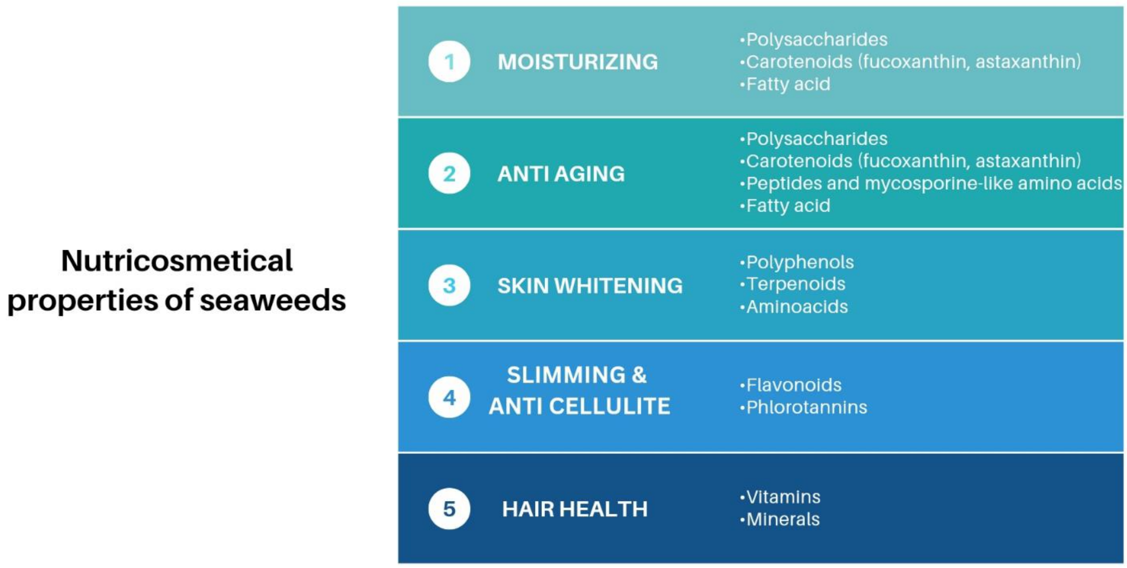
The pigmentation of mammalian skin, hair, and eyes is regulated by the enzyme tyrosinase, which converts L-tyrosine into melanin. Increased tyrosinase activity can lead to hyperpigmentation, resulting in age spots and freckles, while decreased activity may cause conditions like vitiligo. Certain algae contain phenols, terpenoids, amino acids, and sugars that act as tyrosinase inhibitors, making them effective skin-whitening agents. Red algae, particularly rich in mycosporine-like amino acids, are valuable sources of bioactive compounds for the cosmeceutical industry focused on skin lightening and depigmentation.

Slimming and anti-cellulite effects

"slimming products" are preferred over "anti-cellulite" due to the medical implications of cellulite, which arises from changes in the deep dermis and subcutaneous tissue. Factors such as estrogen levels, microcirculation issues, and genetics contribute to cellulite's multifactorial nature, characterized by an "orange peel" appearance and rough skin texture. Iodine-rich algae, like *Laminaria japonica,* are effective in combating cellulite by regulating thyroid hormone synthesis, which enhances lipolysis and facilitates fatty acid penetration into mitochondria.

Effects on Hair health

Marine macroalgae are beneficial for hair health due to their rich content of trace minerals and vitamins, particularly B vitamins, which support hair growth. Seaweeds like P. *palmata* and E. *cava* have shown positive effects on hair regeneration and growth in studies. Compounds such as dieckol from E. *cava* promote dermal papilla cell proliferation, enhancing hair follicle growth. Additionally, glycosaminoglycans found in macroalgae improve nutrient transfer to hair cells, contributing to stronger and thicker hair.



Oral care
Methanolic extracts of certain macroalgae like *Enteromorpha linza*, *Sargassum sagamianum* and *Ulva pertusa* have shown strong inhibitory effects against oral pathogens *Prevotella intermedia* and *Porphyromonas gingivalis*, with phenolic compounds identified as the main active agents.

EXTRACTION AND ISOLATION TECHNIQUES-BIOACTIVE COMPOUNDS
Solvent Extraction : This method uses liquids (solvents) to pull out useful compounds from seaweeds. Different solvents are used depending on the type of compounds:

- Water-based solvents (like methanol or ethanol) are good for water-soluble compounds.
- Oil-based solvents (like dichloromethane) are used for oil-soluble compounds.

Ultrasound-Assisted Extraction (UAE) : This technique uses sound waves to help break open the seaweed cells, making it easier to extract the beneficial compounds.

Supercritical Fluid Extraction (SFE) : This advanced method uses carbon dioxide in a special state (supercritical) to extract specific compounds without damaging them. It's very effective for delicate substances.

Chromatographic Techniques : After extracting the compounds, methods like High-Performance Liquid Chromatography (HPLC) and Thin Layer Chromatography (TLC) are used to separate and identify the different bioactive compounds.

EFFICACY AND SAFETY
Seaweeds are increasingly recognized for their efficacy and safety in nutricosmetics, offering a range of bioactive compounds such as polysaccharides, peptides, and polyphenols. These compounds exhibit antibacterial, antioxidant, and anti-inflammatory properties, contributing to skin health and wellness. The use of seaweed extracts in cosmetics supports a natural approach to skincare, aligning with consumer demand for eco-friendly products.

Nutricosmetics derived solely from seaweeds demonstrate notable efficacy and safety. Research indicates that macroalgae extracts possess skin-moisturizing, anti-melanogenic, and anti-cellulite properties, supported by clinical studies confirming their safety and effectiveness. Seaweeds are rich in bioactive compounds like polysaccharides, proteins, and antioxidants, contributing to their beneficial effects on skin health. Additionally, they exhibit low cytotoxicity and allergenic potential, making them suitable for cosmetic applications.

In general, fucoidan and fucoxanthin products derived from seaweed are appearing more often on the nutricosmetic market. As whole macroalgae and its extracts gain an increased presence in the nutraceutical sector, their untapped potential for the antiaging market as a detoxifying ingredient and micronutrient provider is being realized.

CONCLUSION
The integration of seaweeds into nutricosmetics represents a significant advancement in skincare, leveraging their rich bioactive compounds to enhance skin health and appearance. With growing consumer demand for natural and sustainable ingredients, seaweeds offer unique benefits, including moisturizing, anti-aging, and skin-whitening properties. Their diverse compounds, such as polysaccharides, proteins, and phenolics, contribute to their efficacy and safety, making them suitable for various cosmetic applications. As research continues to unveil their potential, seaweeds

are poised to play a pivotal role in the future of the beauty industry, aligning with trends towards eco-friendly and health-conscious products.

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Article ID : 04/IX/44/0924

IMPORTANCE OF SERI -TOURISM ON RURAL DEVELOPMENT OF ASSAM

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Abstract

Sericultural tourism integrates sericultural activities with tourism in rural areas and enables tourists to communicate with locals and experience sericulture -themed experiences. Seri - tourism aims to evaluate the tourism potential of Sericultural rural areas to make economic gains for the local people through tourism activities. By giving emphasis on seri- tourism in the state of Assam it will not only help to uplift the living standard of sericulture farmers but also help to preserve the greenery through afforestation.

Keyword : Tourism, Sericulture, Rural development, aforestation

Introduction

Assam often hailed as one of India's most bountiful and untouched region is nestled in North East India and is an abode of natural beauty and diverse history. Known as the 'Land of Blue Hills and Red River', Assam boasts wild forests, mighty rivers, and vast tea plantations. Kaziranga National Park which is famous all over the world as the home to the one-horned rhino and listed as the UNESCO world heritage site is also located in Assam. Renowned for the unique golden silk *i,e* Muga, Assam possesses monopoly for its production in the world. With the majestic Brahmaputra River, magnificent hills, and rich flora and fauna, Assam embodies every tourist's paradise, serving as the gateway to the enchanting and unexplored northeastern part of India. A major populace of the state depends upon agriculture as their main source of income followed by other allied sectors like sericulture, fishery, veterinary etc. Sericulture a vital mode of livelihood for especially the rural population of Assam is defined as the rearing of silkworm to produce silk. Silk is considered a prestigious textile fibre and is also sometimes referred to as the 'Queen of Textiles'. It's important qualities like, tensile strength, breathability, softness, hypoallergic, sustainability and cultural significance makes it a fibre of demand throughout the world. Sericulture represents labour intensive, low-investment, small scale industry that caters to both marginal and small landholders due to its potential for high returns, short gestation period and year round employment opportunities for family members. It serves as an important tool for rural construction, benefiting the weaker section of the society. Sericulture is broadly classified into two distinct sectors *viz*., mulberry and *vanya*. Mulberry sericulture is concerned with rearing of mulberry silkworm (*Bombyx mori*) for production of mulberry silk and *vanya* sericulture is concerned with the rearing of different varieties *i.e* eri (*Samia ricini* Donovan), muga (*Antheraea assamensis* Helfer), tropical tasar (*Antheraea mylitta* Drury) and oak-tasar (*Antheraea proylei* Jolly) silkworm. Among all the silk producing states of India, Assam plays a vital role for the production of all four types of silk. Farmers in rural Assam are engaged in various activities like silkworm host plant cultivation, seed production, silkworm rearing to produce silk cocoons, reeling the cocoons to unwind the silk filament, yarn manufacturing, weaving and fabric preparation from silk (Kumaresan, 2008; Anitha, 2011). It provides income generation to farm families throughout the year (Kamili *et.al*., 2000; Roopa *et.al*., 2015; Lakshmannan *et al*., 2011). This popularity of sericulture in Assam has brought up a new concept called seri-tourism. Farms engaged in sericulture are set up in such a manner as to attract tourist and hence giving it a new direction of income generation.

Seri – Tourism

Sericultural tourism integrates sericultural activities with tourism in rural areas and enables tourists to communicate with locals and experience sericulture -themed experiences. Seri-tourism term is used to refer to festivals, museum visits and all cultural tourism activities in rural areas to show the different production stages of silk that tourists are interested in, it is more likely to include accommodation in a seri farm, educational excursions, eating and drinking, rational activities and activities directly linked to the rural environment, using rural product. It is also defined as the set of activities related to the sale of locally produced various sericulture bi-products in the farm. This form of rural tourism today can generate a stable source of economic support for many rural communities. Proper exploitation and management of local resources, as well as the development of diverse seri based enterprises, have the potential to create a regional balance between rural and urban sectors together with providing sustainable livelihood. Seri - tourism aims to evaluate the tourism potential of Sericultural rural areas to make economic gains for the local people through tourism activities.

Importance of Seri-Tourism

1. The educational benefits of seri-tourism:- Seri-tourism may increase urban school children's awareness of rural life and knowledge of sericulture science. It gives urban college students the chance to gain practical experience in sericulture starting from land preparation and plantation of host plant, grainage, rearing methods of silkworms, reeling and spinning, weaving etc.
2. Source of income:- Implementing seri tourism in rural areas can increase farmers income by creating more employment opportunities, improving sericulture labor production efficiency, promoting sales of locally made seri bi- products, optimizing rural industrial structure, bringing in customers from diverse group of people with different origin and ethnicity
3. Desire to learn more about silk bio-product:- Today the world of urban people is consistently looking for new ways of adventures and avenues that not only provide them an escape from their busy and stressful life schedules but also give them new learning and knowledge (Mir *et al*., 2022) . People from this urban areas will get a chance to know the different stages of production as well as the preparation procedure of numerous silk bio-product like Mekhela Chadar, Saree, Shirt, Scarf, Coat, Tye, Gamucha, Curtain etc.
4. Utilization of pupa as food:- The protein content of silkworm pupae is about 21.5%, which is higher than that of other typical animal products. On a dry-weight basis, the protein content of silkworm pupae has been reported to be as high as 49%–54% (Longvah *et al*.,2011; Nowak

et al.,2016). The proteins of silkworm pupae are considered complete proteins because of their high content of essential amino acids. In fact, silkworm contains all the amino acids required by the human body and in the appropriate proportions based on the recommendations of the FAO/World Health Organization (WHO) (Kohler *et al*.,2019; Ni *et al*.,2003; Wang *et al*.,2009; Yang *et al*.,2009; Zhou & Han,2006). Preparation of pickle form pupa can increase the additional income of village people as well as tourist will get a opportunities to buy and taste it.

5. Reduce deforestation and increase afforestation: - Silkworm feeds different types of host plant to complete its lifecycle. To produce more income one would have to go for more plantation, as a result it will increase the numbers of plants along with greenery. Without disturbing the natural ecosystem the production of silk can be maximized as well as it will help in sustainable development of rural areas.
6. Peace and serenity: - In urban areas each person makes an effort to work harder in a variety of ways to earn more money and enjoy modern amenities. Peace is therefore difficult to find in this system. It is possible to find a quite environment through tourism. Due to its location from cities and closeness to nature, seri-tourism can enhance calmness and tranquility among urban people.
7. Investments:- Seritourism will attract companies to make investments on rural cottage industries.
8. World market:- World market will open up for rural rearers and weavers due to recognition.
9. Encouragement of people to take up seri tourism:- Due to exposer of people in seri farms, as well as knowledge about the entire silk production process and the earning from it, it will help to motivate more people to take up seri tourism as income source.

Conclusion

Since the concept of seri-tourism is new and different, this will take time to popularize in the state. Looking at this interdependence between the tourism and sericulture sectors it can be concluded that the tourism has a significant influence on economic growth of the farmers of rural areas. Seri-tourism can help to increase the income of the farmers, provide opportunities to school, college student as well as urban people to know about the different stages of silk production, lead to more employment generation and motivate the rural youth to take up seri-tourism as their main source of income. By giving emphasis on seri- tourism in the state it will not only help to uplift the living standard of sericulture farmers but also help to preserve the greenery.

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ISSN : 2583-0910
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Article ID : 04/IX/45/0924

BREAST-FEEDING-A COMPLETE BOON FOR TODDLER

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Introduction

Several health organizations, including the World Health Organization (WHO) and the National Health and Medical Research Council (NHMRC) of Australia, support the idea that breastfeeding is the healthiest choice for infants. Both organizations recommend exclusive breastfeeding for the first six months of a baby's life. They also advise continuing breastfeeding and complementary foods for a minimum of two years (WHO) and twelve months (NHMRC) respectively. Despite 133 million babies being born annually, only about one-third of newborns aged 0-5 months are exclusively breastfed (UNICEF 2006). Successful breastfeeding is an important skill for parents to learn, and it is recommended to breastfeed the baby within 30 minutes of a normal delivery or four hours following a cesarean section. It is advised not to give pre-lacteal foods such as glucose, purified water, or honey, as the sucking reflex is most pronounced at birth. Breastfeeding has been associated with a reduced risk of various conditions such as leukemia, necrotizing enterocolitis, celiac disease, and inflammatory bowel disease, as well as lower rates of atopic, and cardiovascular disorders, and a lower risk of infant mortality. It is also linked to cognitive benefits such as higher IQ, lower rates of attention deficit disorder, better neurodevelopment, and improved behavioral and developmental outcomes. Globally, breastfeeding can prevent 13% of infant deaths and decrease the incidence of sudden infant death syndrome by 36%. Apart from the health benefits, breastfeeding also leads to savings on related health costs, reduces the need for formula, and has a positive impact on the environment."

Colostrum

The mammary gland secretes a thick, yellowish fluid in the first two- or three days following delivery. This is called colostrum and is different from mature milk. It is secreted in modest amounts (10–40 ml) and is high in protein. Colostrum has a lower overall fat content than mature milk. It contains larger concentrations of arachidonic acid and docosahexaenoic acid (DHA) relative to total fatty acids than does mature milk. It contains higher levels of vitamins K and A. There is less lactose present. Additionally, the levels of riboflavin, biotin, pantothenic acid, and niacin are low. The amount of vitamin C secreted is comparable to that of mature milk.

An infant receives its first immunization with colostrum. It contains a material with potent antiviral action that resembles interferon. Because colostrum contains B12 binding protein, E. Coli and other bacteria are unable to thrive on B_{12}. Antibodies against viral illnesses like influenza, measles, polio, and smallpox are also present. There are more of the cell-maturing-promoting enzymes lysozyme, peroxidase, and xanthine oxidase in colostrum. Large amounts of protective chemicals included in colostrum aid in the growth and maturity of the baby's digestive system. Colostrum aids a newborn in passing their first stool and aid in the removal of extra bilirubin, thus averting jaundice.

Table: Composition of colostrum

Nutrient	Amount
Energy kcal	58
Lactose g	5.3
Protein g	2.7
Fat g	2.9
Calcium mg	31
Phosphorus mg	14
Iron mg	0.09
Carotene I.U.	186
Vitamin A.I.U.	296

Source: Guthrie A.H., 1989, Introductory Nutrition, Times Mirror/Mosby College Publishing, St. Louis

Benefits of Breastfeeding:

To Infants:

Protection Against Infections: Breastfeeding provides robust protection against infections such as respiratory and gastrointestinal illnesses. Breastfed infants experience significantly fewer severe respiratory infections than those who are formula-fed.

Neurodevelopment and SIDS: Breastfeeding supports brain development in both preterm and full-term infants and is associated with better cognitive outcomes. It also reduces the risk of sudden infant death syndrome (SIDS).

Asthma and Allergies: Although the relationship between breastfeeding and asthma or allergies is still debated, some research suggests that breastfeeding may reduce the risk, especially in children with a family history of these conditions.

Chronic Diseases: Breastfeeding may help prevent childhood obesity, which can persist into adulthood, and lower the risk of chronic diseases like heart disease, diabetes, and high blood pressure.

Other Health Benefits: Breastfeeding may protect against certain childhood cancers, inflammatory bowel disease, celiac disease, and reduce the likelihood of dental problems and pyloric stenosis.

To Mothers:

Cancer Prevention: Breastfeeding lowers the risk of breast and ovarian cancers, with longer and more exclusive breastfeeding providing greater protection.

Postpartum Recovery: Breastfeeding aids in postpartum recovery and can delay the return of fertility.

Additional Benefits: Breastfeeding may reduce the risk of rheumatoid arthritis, support postpartum weight loss, lessen maternal depression, and strengthen the bond between mother and child.

Economic Benefits:
Breastfeeding can significantly reduce healthcare costs by preventing numerous illnesses. However, current economic analyses often underestimate these benefits by focusing only on a limited number of infant conditions and not considering long-term effects.

Low breastfeeding rates are linked to cases of breast cancer, hypertension, and heart attacks each year among U.S. mothers, leading to societal costs of $17.4 billion due to premature deaths and $860 million in healthcare expenses. The American Academy of Paediatrics notes that if 90% of mothers exclusively breastfed for six months, the U.S. could save $13 billion annually.

Disadvantage of non-breastfeeding child
Ear infections, or otitis media: In the first year of life, 44% of newborns suffer an ear infection at least once. This risk is twice for formula-fed infant compared to those who are breastfed exclusively for over three months.

Reduced Infection of the Respiratory Tract: According to research, compared to babies who were nursed for more than four months, non-breastfeeding newborns had a 3.6-fold higher chance of being admitted to the hospital during their first year of life.

Intestine infection: Numerous studies have indicated that formula-fed newborns may be more susceptible to diarrhea and gastroenteritis. Mix-fed babies are included in this as well.

Enterocolitis necrotizing (NEC): This terrible condition affects premature infants and causes the intestinal wall to get infected and perhaps destroyed by germs. There is a 15% case fatality rate for this dangerous virus. There is a 2.4-fold increase in the risk of NEC if a child is not breastfed.

Diabetes and Obesity: According to studies, compared to newborns who are nursed exclusively, infants who are fed formula have a 1.1–1.3 times higher chance of being obese as adults. Formula feeding throughout infancy is also linked to a 1.6-fold increased risk of Type 2 Diabetes. A 1.2–1.4-fold greater incidence of Type 1 Diabetes is linked to breastfeeding for fewer than three months.

Paediatric Leukaemia: A 1.3-fold increased incidence of acute lymphoblastic leukemia is suggested by meta-analyses of studies in children who were fed formula as opposed to those who were nursed for less than six months. Research has also shown that infants who are formula-fed have a 1.2-fold increased risk of acute myeloid leukemia when compared to infants who are breastfed for more than six months.

Cognitive Development: Studies have shown that children who were formula-fed had lower IQ scores than children who were breastfed. Studies have also discovered indications of developmental variations with shorter nursing periods.

Comparison between human milk and cow's milk

ISSN : 2583-0910
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Here's a well-organized table comparing the nutritional content of cow's milk (semi-skimmed, pasteurized) and human milk (mature) per 100g:

Nutrients	Cow's Milk (semi-skimmed, pasteurised) per 100g	Human Milk (mature) per 100g
Sodium (mg)	43	15
Potassium (mg)	156	58
Calcium (mg)	120	34
Magnesium (mg)	11	3
Phosphorus (mg)	94	15
Iron (mg)	0.02	0.07
Copper (mg)	Trace	0.04
Zinc (mg)	0.4	0.3
Chloride (mg)	87	42
Manganese (mg)	Trace	Trace
Selenium (ug)	1	1
Iodine (ug)	30	7
Retinol (ug)	19	58
Carotene (ug)	9	24
Vitamin D (ug)	Trace	Trace
Vitamin E (mg)	0.04	0.34
Thiamin (mg)	0.03	0.02
Riboflavin (mg)	0.24	0.03
Niacin (mg)	0.1	0.2
Vitamin B6 (mg)	0.06	0.01
Vitamin B12 (mg)	0.9	Trace
Folate (ug)	9	5
Pantothenate (mg)	0.68	0.25
Biotin (ug)	3.0	0.7
Vitamin C (mg)	2	4

Source: FSA, 2002

Nutritional Composition

Proteins:

Human Milk: Contains a lower overall protein concentration with a higher proportion of whey proteins, which are easier for infants to digest. The protein in human milk is specifically designed to support human infants' brain development and growth.

Cow's Milk: Has a higher protein content, predominantly casein, which is more difficult for infants to digest. Cow's milk is tailored for the rapid growth of calves rather than human infants.

Fats:

Human Milk: Rich in essential fatty acids such as DHA and ARA, which are vital for brain and eye development. It also contains lipase, an enzyme that assists in fat digestion.

Cow's Milk: Contains more saturated fats but lacks the specific fatty acids and digestive enzymes found in human milk.

Carbohydrates:
Human Milk: High in lactose, which aids in calcium absorption and fosters the growth of beneficial gut bacteria.

Cow's Milk: While it also contains lactose, it is in lower amounts and lacks the unique oligosaccharides present in human milk that help develop the immune system and support gut health.

Vitamins and Minerals
Iron:
Human Milk: Has less iron compared to cow's milk, but it is more easily absorbed by infants, efficiently meeting their needs without overloading their system.

Cow's Milk: Contains more iron, though it is less bioavailable, making it harder for infants to absorb effectively.

Calcium:
Human Milk: Provides sufficient calcium for an infant's needs, balanced with magnesium and phosphorus to enhance absorption.

Cow's Milk: While higher in calcium, the mineral balance can sometimes hinder absorption, and it is more suited to the rapid bone development seen in calves.

Vitamin D:
Human Milk: Naturally low in vitamin D, which is why supplementation is recommended for exclusively breastfed infants.

Cow's Milk: Often fortified with vitamin D to help meet the daily requirements, especially for bone development.

Immune System Benefits
Human Milk: Packed with antibodies, immunoglobulins, and white blood cells that help shield infants from infections and diseases. It also contains antimicrobial agents like lysozyme and lactoferrin.

Cow's Milk: Lacks the immune-boosting components specific to human milk and is not intended to protect human infants from pathogens.

Digestibility
Human Milk: Easily digested due to its unique protein structure and the presence of enzymes like lipase. Breastfed infants typically have softer, less odorous stools.

Cow's Milk: More challenging for infants to digest because of its higher casein content, which can lead to digestive issues such as constipation or colic. It is also more likely to cause allergic reactions in infants.

Environmental and Ethical Considerations
Human Milk: Environmentally sustainable as it does not require packaging, processing, or transportation. It is a natural, renewable resource.

Cow's Milk: Production involves significant environmental impacts, including greenhouse gas emissions, land use, and water consumption. Ethical concerns also arise around animal welfare in dairy farming.

Conclusion

Human milk is ideally suited to meet the nutritional and developmental needs of human infants, offering superior digestibility, immune protection, and overall health benefits. Thus it should be the foremost and important food given to the infant after birth immediately to give the infant a healthy life ahead.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/46/0924

SMART IRRIGATION: LEVERAGING AI FOR SUSTAINABLE AGRICULTURE IN WATER-LIMITED REGIONS

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Abstract

Water scarcity, driven by climate change and population growth, poses critical challenges to agriculture, especially in regions vulnerable to drought and limited water resources. Maximizing crop yields in these conditions necessitates efficient irrigation management. This study explores the role of Artificial Intelligence (AI) in increasing irrigation practices to improve water use efficiency and enhance crop yields. AI-driven technologies, including predictive analytics, real-time monitoring, and automated irrigation systems, enable farmers to optimize water distribution, minimize wastage, and ensure precise water delivery at essential growth stages. With adopting AI-enhanced irrigation strategies, farmers can conserve water, promote sustainable agricultural practices, and secure food production in water-limited environments. The integration of AI into irrigation management offers a promising solution to the pressing challenges of water scarcity and agricultural productivity, ensuring that water resources are used effectively to support crop growth and resilience in the face of changing environmental conditions.

Introduction

As global agricultural demands continue to rise, optimizing irrigation management has become crucial for sustaining food production, particularly in regions with limited water resources. Agriculture remains the largest consumer of freshwater, accounting for approximately 70% of global water withdrawals (Foley *et al.*, 2011). However, traditional irrigation practices often rely on fixed schedules and manual adjustments, which are not always responsive to the dynamic needs of crops and the unpredictable nature of weather patterns. This can lead to inefficient water use, with significant portions of water being lost to evaporation, runoff, or seepage, ultimately reducing the overall effectiveness of irrigation systems (Postel, 2017).

In recent years, Artificial Intelligence (AI) has emerged as a transformative technology capable of enhancing the precision and efficiency of irrigation management. AI technologies can analyze a wide range of data, including weather forecasts, soil moisture levels, and crop growth stages, to optimize irrigation schedules and improve water distribution. By integrating AI-driven systems, farmers can ensure that crops receive the optimal amount of water at critical growth stages, which not only conserves water but also maximizes crop yields (Jiménez & Navarro, 2020).

One of the significant benefits of AI in irrigation management is its ability to predict future water needs based on real-time and historical data. Predictive analytics powered by AI can forecast periods of water stress and adjust irrigation schedules accordingly, reducing the risk of crop failure and enhancing agricultural productivity (DeJonge *et al.*, 2015). This proactive approach to irrigation management is particularly valuable in regions prone to water scarcity, where efficient water use is essential for sustaining crop yields (Yang *et al*., 2022).

AI also enables real-time monitoring and control of irrigation systems through the integration of Internet of Things (IoT) devices. These devices allow for remote monitoring of soil moisture levels and automate irrigation processes, ensuring that water is applied precisely when and where it is needed (Zhang *et al*., 2019). This level of precision not only improves water use efficiency but also supports sustainable agricultural practices by reducing water wastage (Fernández *et al*., 2018). By adopting AI-enhanced irrigation strategies, farmers can significantly improve water use efficiency and boost crop yields, contributing to the sustainability of agricultural practices. The integration of AI into irrigation management represents a critical step towards addressing the challenges posed by increasing agricultural demands and the need for efficient water use in the face of changing environmental conditions (Wang *et al*., 2021).

Implementing AI-Driven Irrigation Management

AI-driven irrigation management involves a systematic approach that integrates advanced technologies to enhance water use efficiency and boost crop yields. This process includes several critical steps, each contributing to a more precise and sustainable irrigation practice.

Data Collection and Analysis: The foundation of AI-driven irrigation management is robust data collection. Sensors placed in the field gather real-time information on soil moisture, weather conditions, and crop growth stages. This data is crucial for understanding the specific water needs of crops at different times (Jiménez & Navarro, 2020). AI systems then analyze this data, identifying patterns and making predictions about future water requirements based on historical and current information (DeJonge *et al*., 2015).

Predictive Analytics: One of the core strengths of AI in irrigation management is its ability to use predictive analytics. By analyzing past and present data, AI can forecast periods of water stress, allowing farmers to preemptively adjust irrigation schedules. This reduces the risk of crop failure and ensures that water is used efficiently, particularly during critical growth stages (Yang *et al*., 2022). Predictive models help in determining the optimal timing and quantity of water application, leading to improved water use efficiency and higher crop yields (Al-Ghobari *et al*., 2021).

Automated Irrigation Systems: Once the AI system has processed the data and generated insights, it can automatically control irrigation systems. These automated systems adjust water flow in real-time, based on the current needs of the crops and the forecasted weather conditions. This not only conserves water but also ensures that crops receive the precise amount of water needed for optimal growth (Zhang *et al*., 2019). Automation reduces the reliance on manual interventions, allowing for more consistent and precise irrigation practices (Fernández *et al*., 2018).

Monitoring and Feedback Loops: Continuous monitoring is essential for refining irrigation strategies over time. AI systems create feedback loops by constantly evaluating the effectiveness of the irrigation applied. If discrepancies or inefficiencies are detected, the system can adjust on the fly, further enhancing water use efficiency (Foley *et al*., 2011). This adaptive management approach ensures that irrigation remains optimized even as conditions change.

Improving Water Use Efficiency and Yield

AI-driven irrigation management significantly enhances water use efficiency by ensuring that water is applied precisely when and where it is needed. This precision leads to reduced water wastage, lower costs, and improved crop health, ultimately resulting in higher yields. The ability of AI to predict and respond to the needs of crops in real-time ensures that water resources are utilized to their fullest potential (Jiménez & Navarro, 2020).

Benefits of AI in Irrigation Management

Water Conservation: AI systems reduce water usage by applying it only when necessary, which is crucial in areas facing water scarcity (Chukalla *et al*., 2017).

Increased Crop Yields: By optimizing irrigation schedules, AI ensures that crops receive adequate water, leading to higher productivity (Fernández *et al*., 2018).

Labor Efficiency: Automation reduces the need for manual intervention, allowing farmers to focus on other critical tasks (Foley *et al*., 2011).

Sustainability: AI promotes sustainable agricultural practices by optimizing resource use and minimizing environmental impact (Wang *et al*., 2021).

Challenges and How to Mitigate Them

High Initial Costs: Implementing AI systems can be expensive. This challenge can be mitigated by government subsidies, grants, and cost-sharing programs, which make AI technologies more accessible to farmers (Jiménez & Navarro, 2020).

Technical Expertise: Operating AI systems requires technical knowledge. Providing training programs and developing user-friendly interfaces can help farmers adapt to these technologies (Yang *et al*., 2022).

Data Privacy and Integration: Ensuring the security of data and integrating AI with existing systems can be complex. Developing standardized protocols and robust cybersecurity measures can address these concerns (Zhang *et al*., 2019).

Accessibility in Developing Regions: Access to AI technology may be limited in some developing regions. International cooperation, technology transfer initiatives, and localized research can help bridge this gap (Wang *et al*., 2021).

Conclusion

AI-driven irrigation management presents a transformative solution to the challenges of water scarcity and the need for increased agricultural productivity. By optimizing water use, improving crop yields, and promoting sustainable practices, AI systems offer significant benefits for agriculture in water-limited environments. However, to fully leverage these benefits, it is crucial to address the challenges of cost, technical expertise, and accessibility. Through targeted efforts, AI can play a pivotal role in ensuring the future resilience and sustainability of global agriculture.

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ISSN : 2583-0910
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Peer reviewed
monthly newsletter

Article ID : 04/IX/47/0924

COCONUT OIL IS A LIMELIGHT AMONG ALL OILS IN HUMAN HEALTH

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ABSTRACT

Coconut oil is an integral component of many South Asian diets because of its ability to provide biological activities that benefit human health. This is because some minor components, such as tocopherols and phenolic compounds are retained. Due to the presence of phenolic compounds, VCO exhibits several pharmacological activities, including antioxidant, anti-inflammatory, immunomodulatory, anti-hyperlipidemia, anticancer, antidiabetic, antibacterial, and neuroprotective activities. Despite its health benefits, the consumption of coconut oil is still underrated owing to a lack of supportive scientific evidence. Hence, long-term extensive studies with proper methodologies are suggested to clear all the controversies and misconceptions about coconut oil consumption.

Keywords : Coconut oil, human health, tocopherols, phenolics

Introduction

The coconut tree (Cocos nucifera L.) is often referred to as the “Tree of Life” because of the multitude of uses of each of its parts. Coconut oil (CNO) is an edible oil obtained from the extraction of mature coconut kernels using either mechanical or thermal processing. Because of its high saturated fatty acid and fat content, coconut oil is resistant to oxidative modifications, making it suitable for cooking. Different types of oils prepared from coconut include coconut testa oil (CTO), virgin coconut oil (VCO), and copra oil (CO).

CNO is an oil collected by mechanical milling from copra (the coconut kernel is dried with direct sunlight or with an oven to reduce the content of water). CTO is an emerging form of coconut oil obtained using isopropyl alcohol to extract the coconut testa. VCO, or virgin coconut oil, is obtained by extracting fresh coconut kernels using natural methods and does not undergo any chemical treatments such as refining, bleaching, or deodorizing to produce refined-bleached-deodorized (RBD) oil. In other words, VCO is produced using the wet method, which involves the extraction of oil from coconut milk. Srivastava *et al*., (2018) defined VCO as the oil extracted from freshly harvested, mature coconut kernels using mechanical or natural methods, with or without the application of heat, but specifically without chemical RBD, which does not alter the natural content of the oil. Because VCO is produced differently from RBD coconut oil, the oil obtained has slightly different sensory characteristics. VCO is nearly colourless, with a slightly detectable acid aroma, sweet and salty taste, and perceptible nutty aroma and flavour. On the other hand, RBD coconut oil is distinctively yellow, slightly salty, and has no perceptible aroma or flavour. All types of oils contain similar fatty acids and triglyceride profiles. Virgin coconut oil (VCO) contains a higher content of bioactive compounds, such as vitamin E, sterols, and polyphenols, than refined coconut oil, as the refining process removes a portion of these compounds. Coconut oil is unique among vegetable oils because it contains approximately 48% Lauric Acid in its fatty acid composition. Most of the advantages of Coconut Oil are attributed to the existence of Lauric Acid and the secondary metabolite – monolaurin (Joshi *et al.,* 2020).

Pharmacological benefits of coconut oil

Hypocholesterolemic and cardioprotective effects

Owing to the perceived health benefits associated with CNO, their use and related products has increased over the past decade. Blood cholesterol is explained in terms of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and very-low-density lipoprotein cholesterol (VLDL-C). Derangements in the blood lipid profile are considered an important factor indicating increased risk for cardiovascular complications. Human feeding studies have unequivocally demonstrated the positive impact of coconut fats on HDL-C. Several studies reported that coconut fat increases HDL-C, the so-called 'good cholesterol' in the blood with no significant effect on the TC and LDL-C levels. Two recent systematic reviews indicated CNO consumption significantly increases LDL-C and HDL-C levels (Neelakantan *et al.,* 2020; Teng *et al.,* 2020).

Inhibition and reversal of hepatosteatosis

Hepatosteatosis, a form of non-alcoholic fatty liver disease, is recognized as a major global issue. VCO was found to reduce the effect of paracetamol-induced toxicity by restoring liver function markers and hepatic morphology. Based on the studies conducted so far, it can be concluded that VCOs demonstrate a promising hepatoprotective effect, regardless of the variations in their preparation methods. This hepatoprotective effect of VCO may be partly attributed to its antioxidant activity.

Neuroprotective effect

The possible beneficial effects of cold-pressed VCO in the prevention of neurodegenerative disorders. The treatment of VCO on cortical neuronal cells could improve cell survival by reducing mitochondrial alterations. VCO has several protective effects on cortical neurons disturbed by β-amyloid by enhancing the signalling pathway in cortical neurons and inhibiting the oxidative reactions of some oxidative markers of cellular stress, namely Caspase3 and reactive oxygen species (ROS). The neuroprotective effect of VCO is also shown by the activation of Akt and Erk signalling pathways. The improvement in memory function is associated with cholinergic activity by enhancing the brain's cognitive functions. VCO inhibits acetylcholinesterase activity, as a result of the increased levels of acetylcholine, an important neurotransmitter for the cognitive functions in the brain. VCO has a positive effect on the nervous system by promoting the expression of p-tyrosine hydrolase and nerve growth factors. The neuroprotective effect of VCO also correlated with the antioxidant activity of VCO through the inhibition of lipid peroxidation reactions. Furthermore, the improvement in the nervous system was also enhanced, as indicated by the presence of intracellular signalling molecules in the mesenteric lymph node and thymus.

Anticancer property and chemotherapy protective effect

Several studies reported that CNO is associated with anticancer properties against mammary, colon, liver, lung and oral cancer cells by showing CNO rich in lauric and palmitic acids had a greater inhibition effect on HT- 29 malignant human colon cells than linoleic acid. Apart from its anticancer properties, VCO is emerging as a functional oil to mitigate the undesirable side effects associated with chemotherapy.

Antidiabetic property

Generally, saturated fats might induce insulin resistance in humans, which leads to the development of metabolic disorders such as diabetes. Contrary to popular belief, Virgin Coconut Oil (VCO) has been found to have an anti-diabetic effect by helping to balance blood sugar levels. The phenolic compounds found in VCOs are believed to protect against secondary diabetic complications, such as diabetic nephropathy, by inhibiting the polyol pathway.

Antiobesity effect

Obesity has become a serious health issue around the world due to changing lifestyles and dietary habits. The most interesting argument for the weight control of CNO over other oils is that the energy expenditure of medium-chain fatty acids is greater than long-chain fatty acids. CNO contains a larger proportion of water-soluble medium chain triglycerides which are easily hydrolyzed by lipase absorbed through the intestine and directly sent to the liver to be rapidly metabolized into energy without storing in adipose tissue. Hence, this is thought to decrease the basal metabolic rate. Although CNO has recently attracted attention as a source of weight loss, still, it is still a controversial topic due to the effect of saturated fatty acids and their association with cardiovascular disease.

Antioxidant and anti-inflammatory activities

Antioxidants are compounds that can either delay or inhibit the process of oxidation by scavenging free radicals. When compared to other oils, the number of studies of the antioxidant activity of CNO is limited. Nevertheless, VCO is attracting attention as an oil with high antioxidant activity. The total phenolic content and antioxidant potential were recorded more in groundnut oil, coconut oil and rice bran oil. In addition to antioxidant activity, the anti-inflammatory activity of VCO was proven several years ago. Several research studies have shown that VCO tends to increase antioxidant enzymes and decrease the expression of inflammatory genes such as COX-2, iNOS and IL-6.

Antimicrobial benefits of coconut oil and its derivatives

Antibacterial

VCO has been also reported to have antibacterial activity. CNO has shown to have significant activity against gram +ve bacteria and not any against gram -ve bacteria. Lauric acid, a major fatty acid present in VCO, is reported to be the possible compound responsible for antimicrobial activities. Lauric acid is an effective inhibitor against *S. aureus* and *P. aeruginos* which are common in immuno-compromised individuals.

Antifungal

Lauric Acid has a strong ability to inhibit the growth of *C. albicans* at low concentrations but at higher incubation periods. According to research, VCO in vaginal candidiasis patients improved T-Cells and Cytokine (IL-2) levels.

Antiviral

Viruses that are inactivated to varying extent by monolaurin include HIV, measles, Herpes simplex-1, vesicular stomatitis, visna virus, and cytomegalovirus and the antiviral ability of CNO due to the presence of lauric acid has prompted scientists to start clinical experiments on its potential as a treatment for nCoV-2019 (Rathnasri *et al.,* 2020).

Conclusion

CNO is extremely good in many pharmacological activities and recent studies claim the positive health effects of CNO consumption owing to the presence of medium chain triglycerides. the active components such as phenolics and tocopherols are retained in VCO. These compounds are responsible for biological activities including antioxidant, anti-inflammatory immunomodulatory, anti-hyperlipidemia, anticancer, antidiabetic, antibacterial and neuroprotective as proved by in vitro and in vivo studies. the real value of CNO is obscure due to the limited number of research studies done in Western countries. Hence, properly planned long-term studies may help in understanding the impact of CNO consumption on cardiac health.

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Article ID : 04/IX/48/0924

SCLEROTINIA STEM ROT: DEVASTATING DISEASE FOR OILSEED CROPS

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Abstract

The disease *sclerotinia* stem rot is caused by the notorious fungal pathogen called *Sclerotinia sclerotiorum* which is distributed throughout the world can infect more than 400 crop species. The disease can leads to crop loss from 20% to 70% in oilseeds in different parts of the world. Management of this disease is very important and currently no resistant varieties are available in the market for the disease. Currently only cultural, mechanical, chemical & biological methods are present to manage the disease and this are not economical & feasible approaches for farmers. So there is urgent need to understand the host-pathogen interaction with various advance molecular breeding techniques for breeding the resistance against this pathogen.

Introduction

Sclerotinia stem rot, caused by the fungus *Sclerotinia sclerotiorum,* is a significant threat to oilseed crops worldwide, including rapeseed-mustard, sunflower, and soybean. *Sclerotinia sclerotiorum* (Lib.) de Bary is an unusual necrotrophic pathogen which has the broad host range, double feeding lifestyle and infect more than 400 plant species including oilseeds, pulses, vegetable, grasses & some monocots (Bolton *et al.,* 2006) in the counties like India, China, Australia, United States, Canada, Brazil & Argentina. It is known worldwide with different name as per crop species like, cottony rot, watery soft rot, crown rot, blossom blight, and perhaps most common, *Sclerotinia* stem rot (SSR) or white mold. The oilseeds crops provide sustainability to human living by providing the essential component of cooking i.e. vegetable oil. And this pathogen is reducing the yield and making the global impact on agriculture. This pathogen has a bimodal infection mechanism to cause disease to the host and potentially double lifestyle for feeding which tricks the host to activate the defense mechanism and subsequently leads to disease development (Wang *et al.,* 2019). Oilseed crops have a global importance and this disease can leads to crop damage from 20% to 70%. The host try to defend itself from the pathogen but still no major genes have been identified for resistance against the pathogen in any crop plant. Conventional breeding approaches are lacking due to unavailability of durable resistant sources so there is need to utilize the molecular breeding approaches like genome wide association studies, transcriptome analysis, proteomics and metabolomics to understand the complex host pathogen interaction and breed for resistance in crops.

Oilseed scenario around the world

Oilseed crops are cultivated for their oil-rich seeds, which are processed into vegetable oils and protein-rich meals. The leading crops in oilseeds are soybean, Canola (Rapeseed) Sunflower, Peanut etc. Soybean being the largest producing oilseed crop in the United States, Brazil, and Argentina followed by Canola (Rapeseed) Sunflower, Peanut, mustard in various parts of the world (Ates & Bukowski, 2023). In India, majorly nine oilseed crops are produced in which Rapeseed-Mustard is the leading producer in terms of production is followed by soybean & groundnut accounting 92% share and Rajasthan being the top oilseed producing state followed by Madhya Pradesh, Gujrat and Maharashtra. Despite the fact that we are one of top producer of oilseeds, we are one of the top consumer of oilseed also and 60% of demand of oilseed in India are met through imports from various countries (Rosmann & Verdonk, 2023).

Pathogenesis, infection & crop loss

This pathogen have diverse mode of infection and potential double feeding lifestyles of both biotroph and necrotroph (Hossain *et al.,* 2023). It produces slecrotia, the resting structure of the pathogen which can survive in the soil for more than a decade in absence of suitable host and unfavorable environmental conditions. The sclerotia germinates in favorable environmental conditions like temperature below 30 ^{0}C and relative humidity >80%.

This pathogen infect the host by myceliyogenic infection and carpogenic infection which leads to further infection process and disease development (Fig.1). The infection of the *Sclerotinia* begins with the colonization of plant tissues, often facilitated by the production of oxalic acid and cell wall-degrading enzymes which leads to tissues damage and ultimately death of host plant (O'Sullivan *et al.,* 2021). The typical symptoms are small white or grayish lesions which develops and cover the whole stem resulting in breaking of stem (Fig2). The crop loss of about 20% to 45% was observed which varies from country to country and region to region. In severe conditions crop loss of 70% was also recorded.

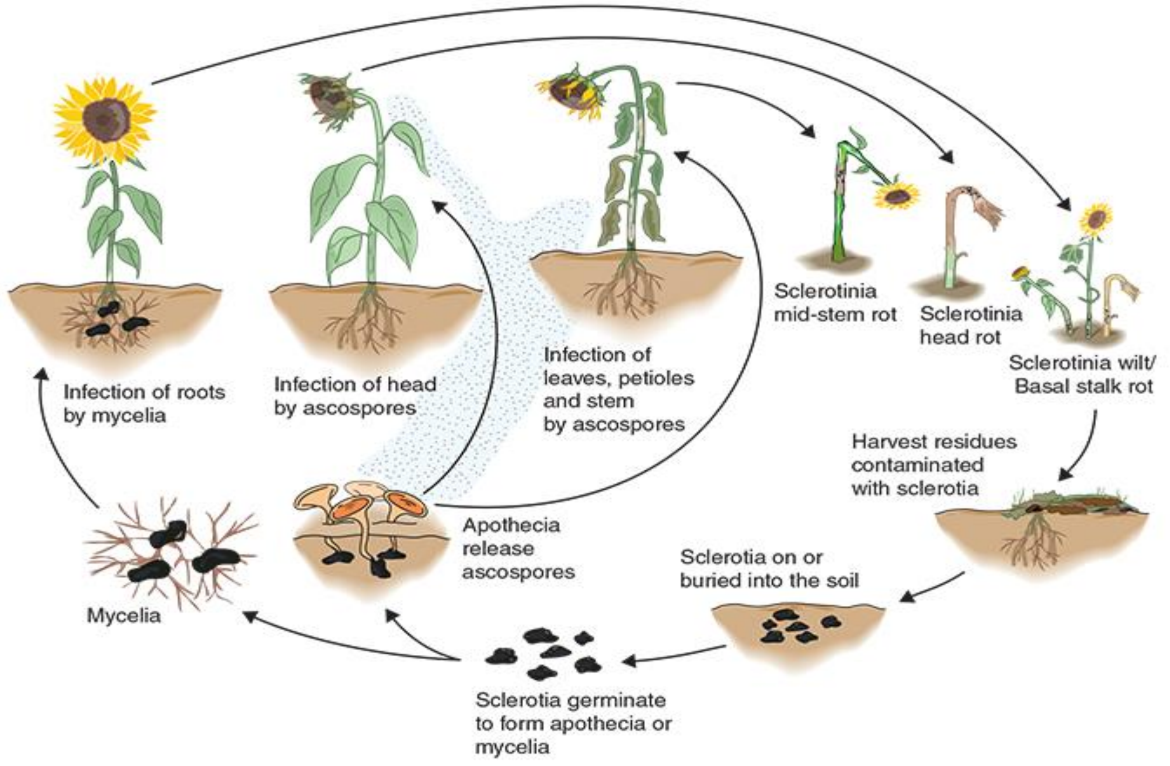

Fig1: Disease cycle of the pathogen

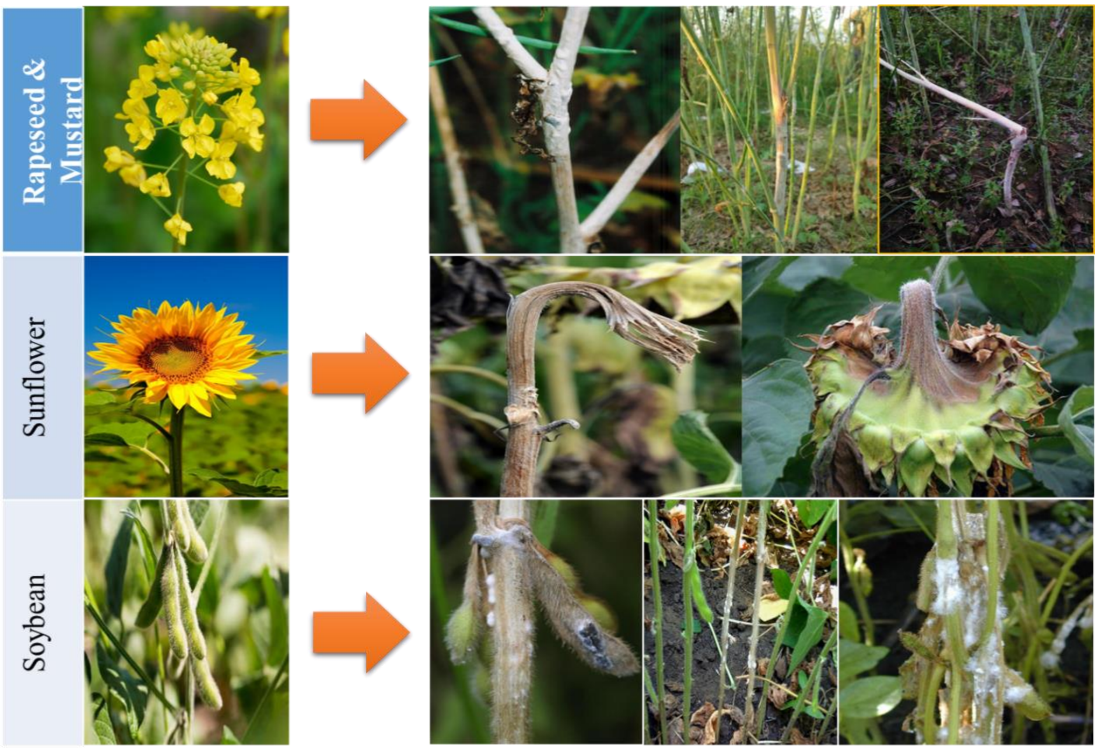

Fig 2: Symptoms of *Sclerotinia* Rot on Rapeseed-mustard, sunflower & soybean.

Oilseeds as vulnerable hosts

Sclerotinia infect and damage almost all the dicots species of various plant families and genera's. But oilseeds like soybean & sunflower is particularly a *Kharif* crop where the rainfall creates favorable conditions for disease development. And Rapeseed-mustard are *Rabi* crop requiring cold weather and low temp for its overall growth and development. As both the crops fall in such situation which are favorable for disease development like temperature below 30 ^{0}C and Relative humidity >80%. The dicot stem are usually solid and undergoes secondary growth increasing in width over time which may be a factor for *Sclerotinia* to infect dicots over monocot but still it's not practically researched.

Approaches to manage disease.

There are many approaches to manage the disease in crop plants like cultural, mechanical, chemical and biological.

Cultural Methods:

Crop rotation: Crop rotation with non-host crops like corn, wheat, sorghum will help to reduce the number of sclerotia in the soil over time by decreasing their viability.

Irrigation management: Irrigation plays an important role in disease development as the pathogen want moisture and humidity to germinate and cause infection. Time of irrigation and frequency of irrigation must be managed properly. In case of rapeseed-mustard, the winter irrigation after 25 December is found to be favorable for disease development.

Habitat diversification: Intercropping with non-host can be used as a good approach to reduce the disease incidence on the crop plant.

Stubble management: The stubbles of infected crops should be properly burned outside the field to reduce the subsequent infection process.

Canopy management: Cropping practices that reduce the intensity and duration of a disease-favorable microclimate within the canopy can lessen *Sclerotinia* severity. Like modulation in crop spacing & avoid closed planting can be helpful.

Chemical and Biological methods:

1. **Fungicides:** Fungicides such as, Benomyl, Prothioconazole, Azoxystrobin can be useful for disease management. Fungicide concentrations varies crop to crop and stage of the crop.
2. **Biocontrol agents:** Several fungi have been shown to be parasites of sclerotia of *S. sclerotiorum*. Among these organisms, *Coniothyrium minitans* and *Tricoderma spp.*, has been found for effectively controlling the disease.

Resistant cultivars:

Resistant varieties are best solution for disease management. Some partially resistant cultivars for *Scletotinia* are found in rapeseed-mustard, sunflower, soybean. And some of the wild relatives of sunflower and rapeseed mustard carrying the resistance are identified through field screening.

Advance approaches for disease management

No true resistant source have been found against this disease in any crop species. So the management of the disease through conventional methods is very difficult and uneconomical. There is an urgent need to identify the durable resistance source for initiating the breeding process and develop the resistant cultivar. Identification of resistance sources can be done through rigorous screening of the germplasm and wild species in all the oilseed crops and understanding the complex host pathogen interaction with different advance techniques will be helpful. Like,

1. Development of effective screening technique for field
2. Genome wide association studies (GWAS)
3. Transcriptomics approach
4. Proteomics approach
5. Metabolomics approach

All the approaches have be found to be effective for understanding the various mechanism governing the resistance in various crops species. GWAS can be helpful to identify the SNPs, QTLs & genes governing the resistance, while transcriptomics will leads to identification of genes governing resistance in partially resistant cultivars in respect to susceptible cultivars. Proteomics and metabolomics can be helpful to understand the complex host-pathogen interaction and the pathways evoking in response to disease. This techniques will also aids in breeding for resistance in different oilseed crops.

Conclusion

Despite its global distribution and severe impact on crops like oilseeds, legumes, and vegetables, *Sclerotinia* stem rot remains poorly managed. Once considered a minor issue, it has become a major disease over the past two decades. Breeding efforts for resistance are limited compared to other diseases. To sustain crop production, especially in oilseeds, we must thoroughly understand host-pathogen interactions using advanced molecular techniques and identify durable resistance sources in both cultivated and wild taxa. Despite global efforts, no major resistance genes or effectors have been identified in oilseed crops.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/49/0924

TECHNOLOGICAL AND ECONOMIC ADVANCEMENTS FOR EFFICIENT AND SUSTAINABLE DAIRY FARMING

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Abstract
The potential for transformation in the dairy farming industry is huge considering technological and economic advances in areas enhancing its efficiency and sustainability. Precision farming, genomic selection, and IoT can yield improvements in feed management, herd genetics, and real-time health monitoring. On the other hand, renewable energy and advanced waste management practices are expected to reduce environmental degradation and foster sustainability. On the other hand, economic strategies that are aimed at enhancing market access and value addition increase the profitability and capacity of farmers for risk management. All these improvements contribute to a more sustainable and profitable dairy farming industry that answers to growing global demand, with lesser impact on the environment.

Keywords : Dairy farming, precision farming, genomic selection, renewable energy.

Introduction

Dairy farming now operates under heavy pressure to increase efficiency and simultaneously decrease the environmental burden. Meeting the ever-expanding demand for milk and milk products globally as a matter of urgency demands technological and economic development. From this, advancements in technologies and economics should provide improvements in productivity, sustainability, and economic efficiency in dairy farming. This article argues for such developments and their implications for the dairy industry's future.

Technological Advances

Precision Farming Technologies

The most extreme advancement of dairy farming is precision farming. It incorporates technologies such as GPS, sensors, and drones for monitoring and managing farm activities with extreme accuracy. GPS technology is applied in mapping and monitoring fields. This optimizes the usage of several resources including water and fertilizers. As noted by Weigel in 2020, on dairy farms, one of the very essential components is the precision feeding system. These systems provide the quantity of feed as per the requirements of each cow, helping the farmer to increase milk production with reduced feed costs (Bewley et al., 2021) . Another transformative technology is the Automated Milking System (AMS). It allows cows to be milked at their convenience that is, at a time consistent with the natural milking patterns which can result in higher milk yields, along with improved animal welfare (Charfeddine & Abo-Saab, 2020).

Genomic Selection and Breeding

Dairy breeding has significantly been advanced by genomic selection, making it easy and accurate to enhance herd genetics. Farmers can expect increased milk production through selection of cows genetically characterized as high producers, resistant to diseases, and best fit for their environment through genetic data analysis (Pryce & Hayes, 2021). This technology is not just about productivity but also sustains the system. For instance, selecting feed efficiency traits can reduce the quantity of necessary feed and emitting methane (Gargiulo *et al*., 2020). Improved prediction and selection for such traits accelerate genetic gain in animals and form the basis for more productive and, at the same time, adapted animal populations.

Internet of Things (IoT) and Data Analytics

The Internet of Things (IoT) plays an important role in the operations of dairy farms by giving real-time data on different aspects. According to Bewley *et al*. (2021), sensors and connected devices pick up data from the animal level regarding health, behaviour, and environmental conditions, whereas the data analysis is carried out to optimize the farm management practice. For example, health monitoring systems fitted with IoT sensors can detect the earliest signs of illness and allow veterinary intervention at a very early stage, thereby reducing the risks of diseases spreading (Zhang & Liu in 2020). Moreover, IoT devices help manage feeding schedules, control the environment, and even predict failures in equipment for improved overall farm efficiency.

Renewable Energy and Waste Management

Modern dairy farming is gearing up to be sustainable. Biogas plants, which turn manure into a form of renewable energy, are increasingly deployed on dairy farms. This offers a twofold bonus, it provides both sustainable energy supply and waste handling, which reduces greenhouse gas emissions (Sharpe & Lutz, 2020). Power for farming is also obtained using solar panels and wind turbines, which in turn helps reduce the carbon footprint of the farm (Steinfeld & Gerber, 2021). Technologies in better waste management, such as anaerobic digestion, have contributed to the conversion of manure into fertilizers, closing the loop on nutrient recycling and minimizing environmental impact.

Economic Advancements

Market Access and Value Addition

Economic strategies are needed to make the dairy farming sector more profitable and sustainable. Two critical dimensions are increasing access to markets and value addition to dairy products. Secondly, well-developed cold chain facilities ensure delivery and storage of milk and its products at optimal temperatures, reducing post-harvest losses and maximizing quality (Olesen & Christensen, 2020). Processing milk into cheese, yoghurt, and butter adds value to farmers' milk and can substantially raise farm incomes. Exploration of niche markets for organic or other value-added dairy products may enable producers to attract premium prices, improving financial returns (Gonzalez & Butler, 2022). Such strategies are oriented toward enhancing profitability while serving consumer preferences for better quality and sustainability in their dairy products.

Financial Instruments and Risk Management

Dairy farmers must have access to financial instruments so as to be in a position to invest in new technologies and practices. In this line, innovations in financial instruments like microcredit, insurance, and cooperative financing have lately helped farmers to manage these risks and invest in productivity-enhancing technologies (Nolan & Lehman, 2020). Insurance products that address the basic dairy farming needs of risk management against price fluctuations and losses due to climate-related events would be very instrumental in reducing income volatility and providing financial stability among these producers' volatility (Zhang & Liu, 2020). Cooperative models provide smallholder farmers with the possibility to pool resources, access markets better, and achieve economies of scale, strengthening their economic resilience and competitiveness.

Sustainable Supply Chains and Certification

The rise in consumer awareness with respect to sustainability is raising demand for more sustainable and socially responsible dairy products. Certification schemes, for example, organic, Fair Trade, and animal welfare certification, allow farmers to access premium markets and improve their incomes correspondingly (Charfeddine & Abo-Saab, 2020). Practices that will contribute towards developing sustainable supply chains include those that lower the use of natural resources, like water and energy, and waste reduction (Gonzalez and Butler, 2022). These will not only meet customer expectations but also ensure long-term business viability and sustainability in dairy farming.

Conclusion

The development of the dairy farming industry in terms of efficiency and sustainability will be continued through technological and economic means. In other words, there will be better productivity, animal welfare, and environmental stewardship through precision farming technologies, genomics selection, IoT, and renewable energy. At the economic level, it involves better market access, product addition, and access to financial instruments, guaranteeing higher profitability and resilience for farmers. It is precisely these innovations that shall play a vital role in meeting the growing global demand for milk products at a time when farming has to be sustainable and economically viable.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed monthly newsletter

Article ID : 04/IX/50/0924

THE EFFECT OF CLIMATE ON SOIL FERTILITY AND CROP PRODUCTION

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Introduction

Climate plays a crucial role in determining the health and productivity of soils, which in turn directly impacts crop production. Variations in temperature, precipitation, and other climatic factors can significantly alter soil properties and influence agricultural outputs. Understanding these effects is vital for developing sustainable farming practices that can adapt to changing climatic conditions. Soil fertility is the capacity of soil to support plant growth by providing essential nutrients and a suitable environment for roots. It is influenced by various factors including climate which plays a significant role in determining soil properties and health. Climate affects soil temperature, moisture, organic matter content and biological activity all of which are crucial for maintaining soil fertility.

Crop production is highly sensitive to climatic conditions, which directly impact growth, development, and yields. Understanding how various climatic factors—such as temperature, precipitation, and extreme weather events—affect crop production is essential for developing strategies to ensure food security and sustainable agriculture.

The Effect of Climate on Soil Fertility:

Temperature Effects on Soil Fertility

Microbial Activity

- **Optimal Temperature Range**: Soil microorganisms, such as bacteria and fungi thrive within specific temperature ranges generally between 15-25°C. These microorganisms decompose organic matter releasing nutrients like nitrogen, phosphorus and potassium, which are essential for plant growth.
- **High Temperatures**: Elevated temperatures can accelerate the decomposition of organic matter leading to a rapid loss of soil carbon. This can deplete the soil's nutrient reserves over time and reduce its structure and fertility. Additionally high temperatures can cause the evaporation of soil moisture further reducing microbial activity and nutrient availability.
- **Low Temperatures**: Cold temperatures slow down microbial activity decreasing the rate of organic matter decomposition and nutrient cycling. This can lead to nutrient deficiencies and lower soil fertility particularly in regions with long winters.

Soil Organic Matter Decomposition

- **Temperature Dependence**: The rate of organic matter decomposition is directly influenced by soil temperature. Warmer temperatures generally increase decomposition rates, but this can lead to a quicker loss of organic matter which is critical for maintaining soil structure and fertility.

- **Seasonal Variations**: Seasonal temperature changes affect soil processes differently. In temperate regions decomposition rates peak during warm seasons contributing to higher nutrient availability. However during cold seasons decomposition slows down leading to a temporary reduction in nutrient release.

Precipitation Effects on Soil Fertility

Soil Erosion

- **Heavy Rainfall**: Intense rain can lead to soil erosion, which removes the nutrient-rich topsoil layer. This process not only reduces soil fertility but also degrades the soil structure making it less capable of retaining water and nutrients.
- **Soil Conservation Techniques**: Methods such as terracing, contour ploughing and the use of cover crops can help reduce erosion. These practices stabilize the soil reduce runoff and maintain soil fertility.

Nutrient Leaching

- **Mechanism**: Nutrient leaching occurs when water percolates through the soil washing away essential nutrients like nitrogen, potassium and magnesium especially in sandy soils. This process can significantly reduce soil fertility over time.
- **Impact on Soil Fertility**: Long-term leaching can deplete soil nutrient reserves, leading to deficiencies that affect crop growth and yield. Fertilization practices must account for this loss to maintain soil fertility.

Waterlogging

- **Effect on Soil Aeration**: Excessive water can saturate the soil leading to anaerobic conditions where oxygen is limited. This affects root respiration and microbial processes reducing nutrient availability and soil fertility.
- **Impact on Nutrient Availability**: Waterlogged soils often experience denitrification where anaerobic bacteria convert nitrates into nitrogen gas resulting in a loss of nitrogen, a critical nutrient for plants.

Drought Conditions

- **Soil Moisture Deficiency**: Lack of rainfall leads to dry soils, which can severely impact plant growth and soil microorganisms. Soil moisture is essential for nutrient solubilization and uptake by plant roots.
- **Soil Compaction**: Dry conditions can cause soil to become hard and compacted, hindering root penetration and reducing the soil's ability to retain water and nutrients. Compacted soils also limit microbial activity, further affecting soil fertility.

Carbon Dioxide Levels and Soil Fertility

Elevated CO_2 Effects

- **Enhanced Photosynthesis**: Increased atmospheric CO_2 levels can boost photosynthesis, leading to greater plant growth and potentially higher organic matter input to the soil. This can improve soil fertility if managed correctly.

- **Altered Soil Microbial Activity**: Changes in plant growth and root exudates due to elevated CO_2 can affect soil microbial communities and nutrient cycling. This can have both positive and negative effects on soil fertility, depending on the balance of these processes.

Nutrient Limitations

- **CO_2 Fertilization Effect**: While increased CO_2 can enhance plant growth, it may also lead to nutrient limitations if the soil cannot supply sufficient nutrients to match the increased demand. This necessitates balanced fertilization to maintain soil fertility.
- **Soil Amendments**: To counter potential nutrient deficiencies, adding organic matter, compost, and other soil amendments can help improve soil structure, nutrient content, and overall fertility.

Extreme Weather Events and Soil Fertility

Impact of Storms and Floods

- **Physical Damage to Soil**: Storms and floods can disrupt soil structure, cause significant erosion, and deposit sediments that alter soil properties. These events can remove topsoil and reduce soil fertility dramatically.
- **Contaminants**: Floodwaters can introduce pollutants, heavy metals, and other contaminants into agricultural soils, adversely affecting soil health and fertility.

Impact of Droughts

- **Soil Degradation**: Prolonged droughts can lead to soil degradation and desertification, reducing soil organic matter and fertility. Dry conditions can also increase the risk of wind erosion, further depleting soil resources.
- **Soil Management Strategies**: Techniques like mulching, conservation tillage, and organic amendments can help retain soil moisture and maintain fertility during droughts. These practices improve soil structure and water-holding capacity, reducing the impact of drought.

Adaptation and Mitigation Strategies

Conservation Agriculture

- **No-Till Farming**: Minimizing soil disturbance helps maintain soil structure and fertility by protecting soil organic matter and reducing erosion. No-till farming also enhances water infiltration and retention.
- **Cover Crops**: Planting cover crops during off-seasons protects the soil from erosion, improves soil structure, and enhances nutrient cycling by adding organic matter and fixing nitrogen.

Water Management

- **Efficient Irrigation**: Drip and sprinkler irrigation systems optimize water use, reducing waste and maintaining soil moisture levels. These systems are especially important in regions with variable rainfall.
- **Rainwater Harvesting**: Collecting and storing rainwater for irrigation during dry periods helps mitigate the effects of insufficient rainfall, ensuring consistent soil moisture levels.

Soil Amendments

- **Organic Matter Additions**: Adding compost, manure, and other organic amendments improves soil fertility by enhancing nutrient content, soil structure, and microbial activity.

- **Biochar**: Incorporating biochar into soil can improve fertility and water-holding capacity while also sequestering carbon, providing long-term benefits to soil health.

Crop Selection and Breeding

- **Drought-Resistant Varieties**: Developing and planting crop varieties that are tolerant to drought and heat stress helps maintain productivity under adverse climatic conditions.
- **Climate-Resilient Crops**: Ongoing research and breeding efforts aim to develop crops that can thrive under changing climatic conditions, ensuring food security and sustainable agriculture.

Effect of Climate on Crop Production

Temperature Effects on Crop Production

Optimal Temperature Ranges

- **Growth and Development**: Each crop species has an optimal temperature range for germination, growth, and maturation. Deviations from this range can significantly affect productivity.
- **Photosynthesis and Respiration**: Temperature influences the rates of photosynthesis and respiration in plants. Optimal temperatures enhance photosynthesis, leading to better growth and yields.

High Temperatures

- **Heat Stress**: High temperatures can cause heat stress, reducing photosynthesis and increasing respiration rates. This imbalance can lead to stunted growth and lower yields.
- **Critical Growth Stages**: Heat stress during critical growth stages, such as flowering and grain filling, can cause substantial yield losses. For example, high temperatures during the flowering of wheat can reduce grain set and quality.
- **Heat-Resilient Varieties**: Breeding heat-tolerant crop varieties is a crucial adaptation strategy to mitigate the impacts of rising temperatures.

Low Temperatures

- **Cold Stress**: Frost and cold temperatures can damage crops, particularly during sensitive stages like seedling emergence and flowering. Cold stress can lead to poor germination, stunted growth, and reduced yields.
- **Frost-Resistant Varieties**: Developing and planting frost-resistant varieties can help reduce the risks associated with cold temperatures.

Precipitation Effects on Crop Production

Water Availability

- **Essential Resource**: Water is crucial for plant processes, including photosynthesis, nutrient uptake, and growth. Precipitation patterns directly influence water availability in the soil.
- **Irrigation Systems**: Efficient irrigation systems, such as drip and sprinkler irrigation, are vital for maintaining crop production, especially in areas with unreliable rainfall.

Excessive Rainfall

- **Waterlogging**: Excessive rainfall can lead to waterlogged soils, which suffocate roots and reduce oxygen availability. This condition hampers root growth and function, leading to poor crop performance and increased susceptibility to diseases.

- **Drainage Systems**: Proper drainage systems are necessary to prevent waterlogging and protect crops from excessive rainfall.

Insufficient Rainfall

- **Drought Stress**: Drought is a major limiting factor for crop production. It reduces soil moisture, impairs nutrient uptake, and leads to plant wilting and death.

Extreme Weather Events

Storms and Floods

- **Physical Damage**: Storms and floods can cause direct physical damage to crops, leading to loss of plant biomass and reduced yields.
- **Soil Erosion**: Flooding can lead to soil erosion, washing away the nutrient-rich topsoil and reducing soil fertility.
- **Crop Protection Measures**: Implementing protective measures, such as windbreaks and reinforced infrastructure, can help reduce the damage caused by extreme weather events.

Droughts

- **Soil Moisture Deficiency**: Prolonged droughts deplete soil moisture reserves, reduce groundwater levels, and lead to crop failures.
- **Irrigation and Water Management**: Efficient irrigation practices and water management strategies are essential to mitigate the impact of droughts on crop production.

Heatwaves

- **Impact on Growth**: Heatwaves can cause heat stress, leading to reduced photosynthesis, accelerated respiration, and poor crop growth.
- **Shading and Cooling Techniques**: Implementing shading and cooling techniques can help protect crops during extreme heat events.

Impact on Crop Yields

Yield Reductions

- **Climate Variability**: Changes in temperature, precipitation, and the frequency of extreme weather events can cause significant variability in crop yields.
- **Yield Stability**: Developing climate-resilient crop varieties and adopting sustainable agricultural practices are crucial for maintaining yield stability under changing climatic conditions.

Crop Quality

- **Nutrient Content**: Climate change can affect the nutrient content of crops. For example, increased CO_2 levels can lead to higher carbohydrate concentrations but lower protein and micronutrient levels.
- **Post-Harvest Quality**: Climate conditions during the growing season can impact the post-harvest quality of crops, affecting storage, processing, and marketability.

Adaptation Strategies

Crop Management Practices

- **Crop Rotation**: Rotating crops with different nutrient requirements and pest resistance can improve soil health and reduce the risk of crop failure.

- **Agroforestry**: Integrating trees and shrubs into agricultural landscapes provides shade, reduces wind erosion, and enhances soil fertility through leaf litter decomposition.
- **Integrated Pest Management**: Implementing integrated pest management practices helps reduce crop losses due to pests and diseases exacerbated by climate change.

Breeding and Biotechnology

- **Climate-Resilient Varieties**: Developing and promoting the use of crop varieties that are resilient to drought, heat, and other climate stresses is essential for sustaining production.
- **Genetic Engineering**: Biotechnology can play a role in developing crops with enhanced tolerance to climate extremes and improved nutrient use efficiency.

Soil and Water Management

- **Soil Conservation**: Practices such as conservation tillage, cover cropping, and organic amendments help maintain soil structure, moisture, and fertility.
- **Efficient Water Use**: Adopting efficient irrigation techniques and water-saving practices is crucial for optimizing water use in agriculture.

Policy and Institutional Support

- **Research and Development**: Investing in research and development of climate-resilient agricultural technologies and practices is essential.
- **Extension Services**: Strengthening agricultural extension services to disseminate knowledge and best practices to farmers is crucial for effective adaptation.
- **Climate-Smart Agriculture Policies**: Developing and implementing policies that promote climate-smart agriculture can help build resilience in the agricultural sector.

Conclusion

Climate significantly impacts soil fertility and crop production, influencing temperature, precipitation, and extreme weather events. While climate change poses substantial challenges, adopting sustainable agricultural practices, developing climate-resilient crop varieties, and implementing efficient soil and water management strategies can help mitigate its effects. Collaboration between scientists, farmers, and policymakers is essential to ensure food security and sustainable agriculture in the face of a changing climate. Continued research, innovation, and investment in climate-smart agricultural practices are critical for building a resilient agricultural sector.

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed monthly newsletter

Article ID : 04/IX/51/0924

YELLOW GULMOHAR- A BEAUTIFUL TREE OF RAINY SEASON IN LOW HILLS OF HIMACHAL PRADESH

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Abstract

Yellow gulmohar or peela gulmohar botanically known as ***Peltophorum ferrugineum*** belongs to the family Fabaceae is a deciduous tree with umbrella shaped canopy. Because of its spectacular display of brilliant yellow blossom rainy season it is mostly grown as an Avenue tree which also functions as a good shade tree providing relief in scorching summer months.

Introduction

Peltophorum ferrugineum commonly known as peela gulmohar or copper pod tree known to be a native of tropical south eastern Asia is an important tree species belonging to fabaceae family. Yellow flowers of this tree during July-August in low hills of Himachal Pradesh. looks marvellous and beauty of flowers with green leaves and rainy season is very pleasing. It is a large deciduous tree reaching to a height of 15-25m. The leaves are bipinnate, 30-60cm long with 16-20 pinnate, each pinna with 20-40 oval leaflet 8-28mm long and 4-10 mm broad. It is a beautiful quick growing ornamental tree with umbrella shape canopy. Flowering season is from April-July and flowers are of yellow colour, produced in large compound raceme up to 20cm long. The fruit is pod which is copper in colour containing 1-4 seeds. Because of its spectacular display of brilliant yellow blossom it is mostly grown as an ornamental tree on the roadside in Indian metropolitan cities (Randhawa and Mukhopadhyay, 2001).

Distribution:- Being a native of tropical South Eastern Asia this tree is prevalent in the Indian subcontinent, South East Asia. Australia and parts of United States.

Botanical description

Kingdom : Plantae
Order : Fabales
Family : Fabaceae
Subfamily: Caesalpinioideae
Genus : *Peltophorum*
Species : *ferrugineum*

Economic importance

Fuel: - pods and wood used for fuel purpose.
Apiculture: - the flowers are used to produce bee forage.
Timber: - it is also used for Timber purpose.
Others: - it is a good tree to control the soil erosion and to provide shade during summer months.

Medicinal uses

The plant is used in different parts of the world for the treatment of several ailments like stomatitis, insomnia, skin troubles, constipation, ringworm, insomnia, dysentery, muscular pains, sores, and skin disorders and is the source of a diverse kind of chemical constituents such as aliphatic alcohols, fatty acids, amino acids, terpenoids, phenolics, flavonoids, alkaloids, steroids etc. The isolated phytochemicals as well as different extracts exhibited numerous biological activities including antimicrobial, antioxidant, cytotoxic, aldose reductase inhibition and antiglycaemic activities (Jash et al 2014).

Avenue plantation of yellow gulmohar

Conclusion

Yellow Gulmohar is an ornamental plant widely used in landscaping and have medicinal importance also. Bright, slightly scented yellow blooms during rainy season looks amazing in low hills of Himachal Pradesh. It is a beautiful ornamental tree, suited for avenues, parks and gardens. The plant is easily grown from seeds. Cutting also strike roots. This is a hardy tree suitable for landscaping in low hills of HP.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 04/IX/52/0924

A MINI REVIEW ON THE IMPACT OF MODERN AGRICULTURAL TECHNOLOGY ON POST-HARVEST LOSSES (PHL) AND FOOD SECURITY

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Abstract

Post-harvest losses have become a global challenge that demands urgent attention, especially in addressing the issue of food insecurity. While several approaches have been employed, many of these solutions could be more sustainable, highlighting the need for intensive research to discover modern agricultural techniques that can effectively combat hunger worldwide. This review explores some innovative approaches, including precision farming, genetic engineering, and soilless farming, as potential solutions to the issue of postharvest losses. It is essential to examine how these modern techniques can be integrated into existing farming systems and find ways to make them accessible to grassroots farmers.

Introduction

Postharvest losses PHL pose a significant problem, particularly for the food production and supply systems of developing nations (Balana *et al.*, 2022). It adds to the supply chain, which raises food costs on the market and increases food security (Sisay, 2022). However, not much is being done to reduce post-harvest losses despite significant resources being allocated to crop protection, irrigation, fertiliser application, and crop planting to maximise productivity (Ibrahim *et al.*, 2022). As a result, valuable agricultural resources that could have been directed toward more profitable goals—such as land, water, labour, management expertise, and other inputs—are wasted (Adepoju, 2014). Thus, Mohammed *et al*. (2024) define post-harvest losses as the decrease in the amount and quality of agricultural produce between the time of harvest and the point at which it is finally consumed. This food loss happens at different points of the supply chain, including harvesting, sorting, transportation, processing, and storage, and spans from crop harvesting to consumption (Aulakh *et al*., 2013). Physical damage (due to rough handling, inappropriate environmental conditions, low-quality transport, and storage containers), inadequate temperature control following harvest, and restricted access to facilities and equipment for adequate cooling, food processing, or storage account for the majority of these losses (Kitinoja, 2016). Farmers' food supply and purchasing power are decreased as a result of these losses, which lowers crop profit margins and ultimately causes world hunger (Kitinoja, 2016). Food security requires more than increasing production and total food supply, it however involves preserving the quality and quantity of the available food for human consumption (Comfort *et al.,* 2022). FAO (2011) defines food security as the state in which all individuals have physical, social, and economic access to enough food that satisfies their dietary needs and food preferences for an active and healthy life at all times. Without a doubt, lowering post-harvest losses is an effective way to combat food insecurity and enhance farmers' livelihoods as the more wastage is prevented, the higher the income that will be realised (Comfort *et al.,* 2022).

Modern Agricultural Technology Strategies

The most common food crops worldwide are wheat, rice, and maize, among other grain cereals, which provide the foundation of staple foods consumed in the majority of developing nations (Ogedengbe *et al.,* 2022). Poor storage conditions, theft, spillage during post-harvest handling activities, and insect pest infestations are the leading causes of PHL in the majority of these cereals (Ibrahim *et al*., 2022). Thus, reducing cereal's post-harvest losses would be an efficient way that can help promote food security, sustainably fight hunger, reduce the agricultural inputs needed for production, and rural development, and improve farmers' livelihoods. Recently, several nations have embraced technology that includes affordable hermetic storage solutions including steel silos, super grain sacks, and Purdue's improved cowpea storage, among others that have become widely popular for efficiently keeping specific cereals. (Comfort *et al.,* 2022).

However, another approach to decreasing postharvest loss that is being explored is the utilisation of modern agricultural technology. Land management, planting, upkeep, harvesting, and harvesting up until the post-harvest phase are all included in this technique (Fitriyah, 2024). Precision farming is another example of a modern approach to postharvest loss reduction. These farming systems adopt the combination of Geographic Information Systems (GIS) with the Global Positioning System (GPS) to manage fields (Bhattacharya & Pandey, 2020). This system of farming has significantly reduced material wastage, leads to improved crop quality, and generally minimises environmental impact. Additionally, these precision technologies make use of automated equipment like agricultural drones, which are used to monitor crop health and deliver targeted treatments, and GPS-controlled tractors, which are capable of extremely accurate operation (Dayana and Kalpana, 2022).

Another contemporary strategy to combat post-harvest loss is the use of biotechnology in applications like genetic engineering and selective breeding, which can increase crop resilience and resistance to disease and environmental stressors, thereby increasing food productivity and thus reducing food insecurity (Ogedengbe *et al.* 2022). Another modern approach is the exploration of hydroponics and aquaponics technologies. This strategy utilises the soilless farming technique, which permits large-scale crop production without requiring sizable areas of land for farming (Fitriyah, 2024). With hydroponics, plants are grown in specialised nutrient solutions instead of soil, which allows for strict control over the environment and other external elements (Demydenko, 2023). Conversely, aquaponics creates a mutually beneficial system in which nutrient-rich fish farming water is utilised to irrigate and nurture plants while simultaneously cleaning the water for fish, combining hydroponics with aquaculture in a symbiotic setting. This method, which combines hydroponics and aquaponics, has the advantage of helping to eradicate pest infections in the soil while providing complete environmental control to the plant, preventing any kind of plant damage. Baba and Adamu, (2021) in their report however emphasis the significance of analysing the impact of all these contemporary agricultural technologies on the production of food crops by regional or grassroots farmers. A thorough understanding of their advantages and limitations, coupled with an exploration of strategies for effectively integrating these technologies at the grassroots level will enable relevant stakeholders to fully leverage their potential in enhancing food crop productivity.

Conclusion

The growing global population has intensified the need for effective food security measures. This review has highlighted several modern agricultural technologies that offer sustainable solutions as well as hold promise for addressing postharvest losses and enhancing food security. Several Modern

Techniques such as precision farming, biotechnology, and soilless farming systems like hydroponics and aquaponics have demonstrated their potential to reduce postharvest losses by enhancing crop resilience, improving storage conditions, and ensuring more efficient use of resources. These innovations not only help preserve the quantity and quality of harvested crops but also contribute to sustainable agricultural practices that are essential for long-term food security. However, to maximise their impact, it is crucial to make these technologies accessible to local farmers, particularly in developing countries where the impact of postharvest losses is most severe. Integrating these innovations with traditional farming practices can significantly boost food production, minimise postharvest losses, and contribute to a more food-secure future for all.

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ISSN : 2583-0910
Agri-India TODAY
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monthly newsletter

Article ID : 04/IX/53/0924

BIOAGENTS IN ORGANIC FARMING: ENHANCING CROP HEALTH AND BIODIVERSITY THROUGH NATURAL SOLUTIONS

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Introduction

In the quest for sustainable agricultural practices, organic and natural farming have emerged as vital approaches to food production that prioritize environmental health, biodiversity, and soil fertility. Unlike conventional farming, which often relies heavily on synthetic chemicals to control pests and diseases, organic and natural farming embrace the use of bioagents—natural organisms and their derivatives—as a primary tool for managing these challenges. The importance of bioagents in these systems cannot be overstated, as they offer a way to control pests and diseases while preserving the integrity of the ecosystem. Bioagents serve multiple functions that make them indispensable in organic farming. They provide a natural means of controlling pests and pathogens, reducing the need for chemical pesticides that can harm beneficial insects, pollute water sources, and lead to the development of resistant pest populations. By promoting the use of bioagents, organic farming supports biodiversity, as these agents often target specific pests or diseases without affecting non-target organisms. This specificity helps maintain a balanced ecosystem where beneficial insects, soil organisms, and plants can thrive.

Moreover, the use of bioagents aligns with the principles of natural farming, which seeks to work with nature rather than against it. In natural farming, the goal is to create a self-sustaining agricultural system where pests and diseases are naturally regulated by the ecosystem. Bioagents, such as beneficial insects, fungi, bacteria, and nematodes, play a crucial role in this process by naturally controlling pest populations and suppressing diseases without the need for synthetic interventions. The importance of bioagents extends beyond just pest and disease management. Their use also contributes to the overall health and productivity of the farm. For instance, certain bioagents enhance soil fertility by promoting nutrient cycling and improving soil structure. Others help plants develop stronger root systems, increasing their resilience to environmental stressors. By integrating bioagents into farming practices, farmers can achieve higher yields and better crop quality while maintaining soil health and reducing environmental impact. Thus, bioagents are a cornerstone of organic and natural farming, offering a sustainable, eco-friendly approach to managing pests and diseases. Their use not only helps protect crops from damage but also supports the broader goals of these farming systems—preserving biodiversity, improving soil health, and promoting the long-term sustainability of agricultural ecosystems. As the demand for organic and sustainably produced food continues to grow, the role of bioagents in agriculture will become increasingly important, providing farmers with the tools they need to produce healthy, high-quality crops in harmony with nature.

Beneficial Insects for Insect Pest Control

Beneficial insects are a cornerstone of pest management in organic and natural farming, offering an eco-friendly and sustainable alternative to chemical pesticides. These insects, which include predators, parasitoids, and pollinators, play a critical role in maintaining the ecological balance within agricultural systems by naturally controlling pest populations. By encouraging the presence of beneficial insects, farmers can reduce the need for chemical interventions, protect crop yields, and promote biodiversity on their farms.

Predatory Insects

Predatory insects are natural enemies of many common agricultural pests. These insects actively hunt and consume pests, thereby reducing their populations and minimizing crop damage. Predators are particularly effective in controlling pest outbreaks because they often consume large numbers of prey throughout their life cycles.

1. **Lady Beetles** (Coccinellidae): Commonly known as ladybugs, lady beetles are voracious predators of soft-bodied insects such as aphids, whiteflies, and scale insects. Both adult lady beetles and their larvae feed on these pests, helping to keep their populations in check. For example, the seven-spotted lady beetle (*Coccinella septempunctata*) is highly effective in controlling aphid infestations in crops like beans, potatoes, and grains. Farmers often introduce lady beetles into their fields as a biological control measure to reduce aphid populations and prevent the spread of diseases that these pests can transmit.
2. **Lacewings** (Chrysopidae):Green lacewings are another group of beneficial insects that are highly effective in controlling a wide range of insect pests. The larvae of lacewings, often referred to as "aphid lions," are aggressive predators that feed on aphids, mealybugs, thrips, and caterpillars. A single lacewing larva can consume hundreds of aphids in its lifetime. Green lacewings (*Chrysoperla carnea*) are commonly used in organic farming to manage pest populations in crops like tomatoes, peppers, and cucumbers. These insects are particularly valued for their ability to control pests in greenhouse environments, where chemical pesticide use is often restricted.
3. **Predatory Mites** (Phytoseiidae): Predatory mites are small but highly effective natural enemies of pest mites and thrips. Species such as *Phytoseiulus persimilis* and *Amblyseius swirskii* are widely used in organic farming to control spider mites, which are common pests in crops like strawberries, tomatoes, and cucumbers. *P. persimilis* is particularly effective against the two-spotted spider mite (*Tetranychus urticae*), which can cause significant damage to crops by feeding on plant tissues. Predatory mites are often introduced into fields or greenhouses as part of an integrated pest management (IPM) strategy, where they help maintain pest populations at levels that do not cause economic harm.

Parasitoids

Parasitoids are another group of beneficial insects that play a crucial role in pest control. Unlike predators, which consume multiple prey throughout their lives, parasitoids lay their eggs inside or on the bodies of host insects. The developing parasitoid larvae feed on the host, eventually killing it. This unique life cycle makes parasitoids highly effective at targeting specific pest species.

1. *Trichogramma* Wasps: *Trichogramma* wasps are tiny, parasitic wasps that are widely used to control caterpillar pests in crops such as corn, cotton, and vegetables. These wasps lay their eggs inside the eggs of pests like the corn earworm (*Helicoverpa zea*) and the European corn borer (*Ostrinia nubilalis*). The *Trichogramma* larvae develop inside the pest eggs, preventing them from hatching and causing damage to the crops. Farmers release *Trichogramma* wasps as part of a biological control program to reduce caterpillar populations and minimize the need for chemical insecticides.
2. *Aphidius* Wasps: *Aphidius* wasps, such as *Aphidius colemani* and *Aphidius ervi*, are effective parasitoids of aphids, which are common pests in many crops. These wasps lay their eggs inside aphids, and the developing larvae consume the aphid from the inside out, eventually killing it. As the larva matures, it turns the aphid into a "mummy"—a hardened shell that contains the developing wasp. After emerging from the mummy, the adult wasp continues the cycle by parasitizing more aphids. *Aphidius* wasps are often used in greenhouse crops, such as peppers and cucumbers, to manage aphid populations and reduce the spread of aphid-transmitted viruses.
3. *Encarsia Formosa*: *E. formosa* is a small parasitic wasp that targets whiteflies, particularly the greenhouse whitefly (*Trialeurodes vaporariorum*). This wasp lays its eggs inside whitefly nymphs, and the developing larvae feed on the nymphs, ultimately killing them. *E. Formosa* is widely used in greenhouse environments to control whiteflies in crops like tomatoes, cucumbers, and ornamentals. By releasing these wasps into greenhouses, farmers can effectively reduce whitefly populations and avoid the use of chemical insecticides.

Pollinators as Indirect Pest Control Agents

While pollinators are not typically considered direct agents of pest control, they play an indirect role in enhancing plant health and resilience, which can help plants better withstand pest attacks. Pollinators such as bees, butterflies, and hoverflies contribute to the pollination of many crops, leading to improved fruit set, seed production, and overall plant vigor. Healthy, well-pollinated plants are often more resistant to pests and diseases, reducing the need for chemical interventions.

Hoverflies (Syrphidae): Hoverflies, also known as syrphid flies, are excellent pollinators of various flowering plants. Their larvae, however, are predators of aphids and other soft-bodied insects. This dual role makes hoverflies particularly valuable in organic farming, where they contribute both to pollination and pest control. Crops like lettuce, carrots, and strawberries benefit from the presence of hoverflies, as they help maintain healthy pollinator populations while also reducing aphid infestations.

Microbial Bioagents for Disease Management

Microbial bioagents are pivotal in organic and natural farming for the management of plant diseases. These naturally occurring microorganisms, including bacteria, fungi, and viruses, offer effective and eco-friendly alternatives to chemical fungicides and bactericides. By harnessing the power of these beneficial microbes, farmers can suppress plant pathogens, enhance crop resilience, and contribute to sustainable agricultural practices.

Beneficial Bacteria

Beneficial bacteria are among the most widely used microbial bioagents in disease management. Species like *Bacillus* spp. and *Pseudomonas* spp. are known for their ability to protect plants against a variety of soil-borne and foliar pathogens.

Bacillus subtilis: One of the most well-known and widely used beneficial bacteria is *Bacillus subtilis*. This bacterium is effective against a broad range of fungal pathogens, including those that cause root rot, damping-off, and leaf spot diseases. *Bacillus subtilis* works by producing antibiotics, such as iturins, fengycins, and surfactins, which inhibit the growth of harmful fungi. It also induces systemic resistance in plants, making them more resilient to future pathogen attacks.

Pseudomonas fluorescens: Another important bacterial bioagent is *P. fluorescens*, which is known for its ability to suppress soil-borne pathogens like Fusarium spp., Pythium spp., and Rhizoctonia spp. *P. fluorescens* produces siderophores—iron-chelating compounds that deprive pathogenic fungi of the iron they need for growth. Additionally, it produces hydrogen cyanide, which has antifungal properties. *P. fluorescens* also promotes plant growth by enhancing nutrient uptake and stimulating root development.

Beneficial Fungi

Beneficial fungi are another critical group of microbial bioagents that play a vital role in disease management in organic and natural farming. These fungi can directly attack and parasitize plant pathogens or create a hostile environment that inhibits their growth.

Trichoderma harzianum: *Trichoderma* spp, particularly *T. harzianum*, are widely recognized for their biocontrol capabilities against a range of plant pathogens, including those that cause Fusarium wilt, root rot, and damping-off diseases. *Trichoderma* spp. operate through several mechanisms: they outcompete pathogenic fungi for nutrients and space, produce antifungal metabolites, and directly parasitize harmful fungi. Additionally, *Trichoderma* spp. can enhance plant growth by producing growth-promoting substances and improving nutrient uptake. Products like RootShield and PlantShield utilize *T. harzianum* to protect crops like cucumbers, tomatoes, and peppers from soil-borne diseases.

Gliocladium virens (now classified as *Trichoderma virens*): This beneficial fungus is effective against diseases such as Pythium damping-off and Sclerotinia stem rot. It acts by producing antifungal compounds and by parasitizing the pathogens. Additionally, *G. virens* induces systemic resistance in plants, making them less susceptible to a range of other pathogens. Commercial products like SoilGard® contain *G. virens* and are used in organic farming to protect a wide variety of crops.

Viruses as Bioagents

While bacteria and fungi are commonly used to control plant diseases, viruses can also serve as bioagents, particularly in managing insect-vectored diseases. These viruses specifically target and kill the insect vectors, thereby reducing the spread of viral diseases in crops.

Baculoviruses: Baculoviruses are a group of viruses that specifically infect insect pests, particularly lepidopteran larvae (caterpillars). While they are primarily known for their role in insect pest management, they also indirectly help manage viral diseases spread by these pests. For example, baculoviruses used against caterpillars that vector viral diseases in crops like cotton and tomatoes can reduce the incidence of these diseases by controlling the pest populations. Products like Helicoverpa NPV and Spodoptera NPV, which are based on baculoviruses, are used to control pests like the cotton bollworm and the armyworm, reducing the damage caused by both the pests and the diseases they vector.

Beneficial Nematodes for Insect Pest Control

Beneficial nematodes are microscopic, worm-like organisms that play a crucial role in controlling insect pests, particularly in organic and natural farming systems. These nematodes, specifically entomopathogenic nematodes, are natural predators of a wide range of soil-dwelling insect pests. By infecting and killing these pests, beneficial nematodes provide an effective, environmentally friendly solution for pest management without the need for chemical insecticides.

Entomopathogenic Nematodes:

Entomopathogenic nematodes (EPNs) belong primarily to two genera: Steinernema and Heterorhabditis. These nematodes are highly effective against a variety of insect pests that reside in the soil or have a stage of their life cycle in the soil, such as larvae and pupae. What makes EPNs particularly valuable in pest management is their ability to actively seek out and infect their hosts, which makes them suitable for controlling pests that are otherwise difficult to reach with traditional control methods. Once an EPN locates a host insect, it enters the insect's body through natural openings such as the mouth, anus, or spiracles. Inside the host, the nematode releases symbiotic bacteria (such as *Xenorhabdus* or *Photorhabdus*) that multiply rapidly, killing the host within 24 to 48 hours. The nematodes then feed on the bacteria and the decaying host tissues, reproduce, and emerge from the dead insect to seek out new hosts, continuing the cycle.

Examples of Beneficial Nematodes in Pest Control

1. ***Steinernema carpocapsae***: One of the most widely used entomopathogenic nematodes, *S. carpocapsae* is highly effective against various insect pests, particularly those in the larval stage. This nematode is known for its ability to control pests such as the codling moth (*Cydia pomonella*), which is a major pest in apple orchards. The codling moth larvae bore into the fruit, causing significant damage. By applying *S. carpocapsae* to the soil or tree trunks where the larvae pupate, farmers can reduce the population of this pest without resorting to chemical insecticides. This nematode is also effective against the black vine weevil (*Otiorhynchus sulcatus*), a pest that attacks a wide range of ornamental plants and berry crops.
2. ***Heterorhabditis bacteriophora***: Another important EPN, *H. bacteriophora*, is particularly effective against pests that spend part of their life cycle in the soil, such as root weevils and white grubs. White grubs, which are the larval stage of beetles like the Japanese beetle (*Popillia japonica*) and the European chafer (*Rhizotrogus majalis*), feed on the roots of turfgrass, causing extensive damage to lawns and crops. *H. bacteriophora* targets these grubs by infecting them in the soil, leading to their death within a few days. This nematode is also effective against the root-knot nematode (*Meloidogyne* spp.), which is a significant pest in vegetable and fruit crops. By reducing the population of root-knot nematodes, *H. bacteriophora* helps protect the crop's root system and improve overall plant health.
3. ***Steinernema feltiae***: *S. feltiae* is another versatile EPN that is used to control a broad range of insect pests, including fungus gnats (*Bradysia* spp.), which are common pests in greenhouse environments. Fungus gnat larvae feed on the roots of plants, causing stunted growth and sometimes leading to plant death. By applying *S. feltiae* to the soil or growing media, farmers and greenhouse managers can effectively manage fungus gnat populations without harming beneficial insects or plants. Additionally, this nematode is used to control thrips, which are notorious for damaging a wide variety of crops by feeding on their leaves and flowers.

Beneficial Botanicals for Insect Pest Control

In organic and natural farming, beneficial botanicals play a crucial role in managing insect pests. These plant-derived substances offer a natural alternative to synthetic chemical pesticides, helping farmers control pests while minimizing environmental impact and preserving the health of non-target organisms. Beneficial botanicals are often extracted from plants with known insecticidal properties and can be used in various forms, including oils, extracts, powders, and sprays. These botanicals are valued not only for their effectiveness but also for their biodegradability and safety for humans and wildlife.

1. **Neem** (*Azadirachta indica*): One of the most widely used and studied botanicals in insect pest control is neem, derived from the seeds of the neem tree (*A. indica*). Neem has been used for centuries in traditional agriculture and is now a cornerstone of organic pest management. The primary active compound in neem is azadirachtin, which acts as an insect growth regulator, repellent, and antifeedant. Azadirachtin disrupts the molting process of insects, preventing them from developing into their next life stage, and reduces their ability to feed, ultimately leading to starvation. Neem oil, which contains azadirachtin, is effective against a wide range of pests, including aphids, whiteflies, beetles, caterpillars, and leafhoppers. It is commonly used on crops such as vegetables, fruits, and ornamentals. In addition to azadirachtin, neem contains several other bioactive compounds, such as nimbin, salannin, and meliantriol, which contribute to its insecticidal properties. These compounds act synergistically to repel insects and inhibit their feeding and reproduction. Neem oil also has fungicidal properties, making it a versatile tool for managing both pests and plant diseases.
2. **Pyrethrum** (*Chrysanthemum cinerariifolium)*: Pyrethrum, derived from the flowers of the chrysanthemum plant (*C. cinerariifolium),* is another highly effective botanical insecticide. Pyrethrum has been used for centuries to control a variety of insect pests and is known for its rapid knockdown effect on insects. The active compounds in pyrethrum are pyrethrins, which affect the nervous system of insects, causing paralysis and death. Pyrethrins are effective against a wide range of pests, including mosquitoes, flies, moths, aphids, and ants. One of the key advantages of pyrethrins is their low toxicity to humans and mammals, as well as their rapid biodegradability in the environment. This makes pyrethrum an attractive option for farmers seeking to manage pests without leaving harmful residues on crops or in the soil. However, it is important to note that pyrethrins can be toxic to beneficial insects, such as bees, so careful application is necessary to minimize harm to non-target species.
3. **Rotenone**: Rotenone is a botanical insecticide derived from the roots of certain tropical plants, including Derris and Lonchocarpus species. It has been used for centuries by indigenous peoples to control pests in crops and is still used today in organic farming. Rotenone works by inhibiting cellular respiration in insects, leading to a loss of energy and eventual death. It is effective against a variety of insect pests, including beetles, caterpillars, and aphids. Rotenone is often used in combination with other botanical insecticides to enhance its effectiveness and broaden its spectrum of control. For example, it is sometimes mixed with pyrethrins to create a more potent insecticide for use on crops such as potatoes, beans, and berries. While rotenone is effective and biodegradable, its use has declined due to concerns about its toxicity to fish and aquatic invertebrates. As a result, it is often used with caution and in specific situations where alternative insecticides may not be as effective.
4. **Essential Oils**: Essential oils, extracted from aromatic plants, are gaining popularity as natural insecticides in organic and natural farming. These oils contain volatile compounds that can repel, deter, or kill insect pests. Peppermint oil, extracted from the peppermint plant (*Mentha piperita*), is known for its strong repellent properties. It is particularly effective

against ants, spiders, and aphids. When applied as a spray or drench, peppermint oil can protect crops like lettuce, cabbage, and tomatoes from pest infestations. Additionally, peppermint oil has antifungal properties, making it a dual-purpose treatment for both pests and plant diseases. Rosemary oil, derived from *Rosmarinus officinalis*, is another essential oil with potent insecticidal properties. It is effective against a variety of pests, including mites, whiteflies, and aphids. Rosemary oil disrupts the nervous system of insects, leading to paralysis and death. It is often used in greenhouse settings to control pests on herbs, vegetables, and ornamental plants. Clove oil, extracted from the clove plant (*Syzygium aromaticum*), is known for its strong insecticidal and repellent properties. It is effective against a range of pests, including mosquitoes, beetles, and cockroaches. Clove oil works by disrupting the cellular membranes of insects, leading to rapid mortality. It is often used in combination with other essential oils to create natural insecticides for use on crops like peppers, tomatoes, and cucumbers.

5. **Capsaicin** (*Capsicum* species): Capsaicin, the active component in chili peppers is another botanical with insecticidal and repellent properties. It is commonly used in organic farming to deter a wide range of pests, from insects to mammals. Capsaicin works by causing irritation and discomfort to pests, deterring them from feeding on treated plants. It is particularly effective against mammals like rabbits and deer, as well as insect pests such as aphids, whiteflies, and beetles. Capsaicin-based products, like Hot Pepper Wax® and Critter Ridder®, are used to protect a variety of crops, including fruits, vegetables, and ornamental plants. In addition to its use as a repellent, capsaicin also has insecticidal properties when applied at higher concentrations. It can disrupt the nervous system of insects, leading to paralysis and death. The use of capsaicin in organic farming is attractive because it is non-toxic to humans and degrades quickly in the environment, making it safe for both consumers and the ecosystem.

Advantages and Disadvantages of Bioagents in Organic and Natural Farming

Advantages:

1. **Environmental Sustainability**: Bioagents promote ecological balance by targeting specific pests and pathogens without harming beneficial organisms. This helps maintain biodiversity and supports the overall health of the ecosystem.
2. **Reduced Chemical Use:** By utilizing bioagents, farmers can significantly decrease or eliminate the reliance on synthetic pesticides, minimizing chemical residues on crops and in the environment.
3. **Targeted Control**: Many bioagents are highly specific to certain pests or diseases, allowing for precise control without affecting non-target species. This specificity helps preserve beneficial insects, such as pollinators.
4. **Soil Health Improvement**: Certain bioagents, such as beneficial bacteria and fungi, enhance soil fertility by promoting nutrient cycling and improving soil structure, which contributes to overall plant health.
5. **Resilience and Adaptation**: The use of bioagents can enhance the natural defenses of plants, making them more resilient to pests, diseases, and environmental stresses.
6. **Safety for Humans and Wildlife**: Most bioagents are non-toxic to humans and wildlife, making them safer alternatives to chemical pesticides. This is especially important for organic farming, where consumer health and safety are paramount.

7. **Long-Term Effectiveness**: Bioagents can lead to sustainable pest management solutions by reducing the likelihood of pest resistance, as they rely on natural ecological processes rather than chemical intervention.

Disadvantages

1. **Time and Labor Intensive**: Implementing a bioagent strategy may require more time and labor than conventional chemical applications, particularly in monitoring and maintaining beneficial populations.
2. **Variable Effectiveness**: The success of bioagents can vary based on environmental conditions, pest populations, and other factors, which can lead to inconsistent pest control outcomes.
3. **Initial Investment**: Farmers may need to invest in training and materials for implementing bioagent strategies, which can be a barrier for some producers.
4. **Limited Shelf Life:** Many bioagents have a limited shelf life and must be applied soon after production or purchase, requiring careful planning and management.
5. **Knowledge Gap**: Effective use of bioagents requires specific knowledge and expertise that some farmers may lack, leading to potential misapplications or ineffective pest control.
6. **Interactions with Other Management Practices**: Bioagents may not be compatible with all agricultural practices, and integrating them into existing systems can be challenging.
7. **Regulatory Challenges**: In some regions, the registration and use of bioagents may face regulatory hurdles that can complicate their availability and implementation in farming practices.

Conclusion

In conclusion, the use of bioagents in organic and natural farming presents a sustainable, eco-friendly approach to managing insect pests and diseases. These natural organisms and their derivatives, such as beneficial insects, microbes, nematodes, and botanicals, offer effective alternatives to synthetic chemicals, supporting the core principles of organic farming. By promoting the use of bioagents, farmers can control pest populations and suppress diseases while preserving biodiversity, improving soil health, and reducing the environmental impact of agricultural practices. The integration of bioagents into farming systems not only enhances crop resilience and productivity but also aligns with the broader goals of sustainable agriculture. As the demand for organic and naturally produced food continues to grow, the role of bioagents will become increasingly significant, providing farmers with the tools they need to produce high-quality crops in harmony with nature.

ISSN : 2583-0910
Agri-India TODAY
visit us at www.agriindiatoday.in
Peer reviewed monthly newsletter

Article ID : 04/IX/54/0924

ADVANCING CROP HEALTH MONITORING WITH MULTISPECTRAL SENSORS

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Abstract

Crop health monitoring is essential for maximizing agricultural productivity and sustainability. Multispectral sensors have emerged as a revolutionary technology in this domain, providing detailed insights into crop conditions that surpass traditional methods. These sensors capture data across multiple wavelengths of light, including visible and near-infrared bands, allowing for early detection of plant stress, precision in nutrient management, and improved irrigation practices. Recent advancements in multispectral technology, including drone integration and data analytics, have further enhanced their effectiveness. This article explores how multispectral sensors are transforming crop health monitoring, highlights recent research, and discusses future directions in this rapidly evolving field.

Keywords: Multispectral, sensor, drone, crop monitoring

Introduction

Multispectral sensors are devices that capture data across multiple wavelengths of light. Unlike standard cameras that only detect visible light (red, green, blue), multispectral sensors measure reflectance in several additional bands, including near-infrared (NIR) and sometimes shortwave infrared (SWIR). This capability allows them to detect features and conditions not visible to the human eye. The principle behind multispectral sensors is based on how different materials absorb and reflect light. Healthy vegetation, for instance, reflects more near-infrared light compared to stressed or diseased plants. By analyzing these reflectance patterns, multispectral sensors can provide detailed information about crop health, soil conditions, and other vital factors. Figure 1 showing the different wavelength bands used across different sensors.

The Mechanism of Multispectral Sensors

Multispectral sensors work by capturing images or data in several wavelength bands. Each band provides different information about the target area:

Visible Light Bands: These include red, green, and blue bands that help in assessing the general appearance of the crop.

Near-Infrared (NIR) Band: This band is crucial for evaluating plant health, as healthy vegetation reflects a higher amount of NIR light.

Shortwave Infrared (SWIR) Band: Sometimes included, this band provides additional insights into plant moisture content and stress levels.

By combining data from these bands, multispectral sensors generate comprehensive images and indices, such as the Normalized Difference Vegetation Index (NDVI), which helps in evaluating plant health and stress.

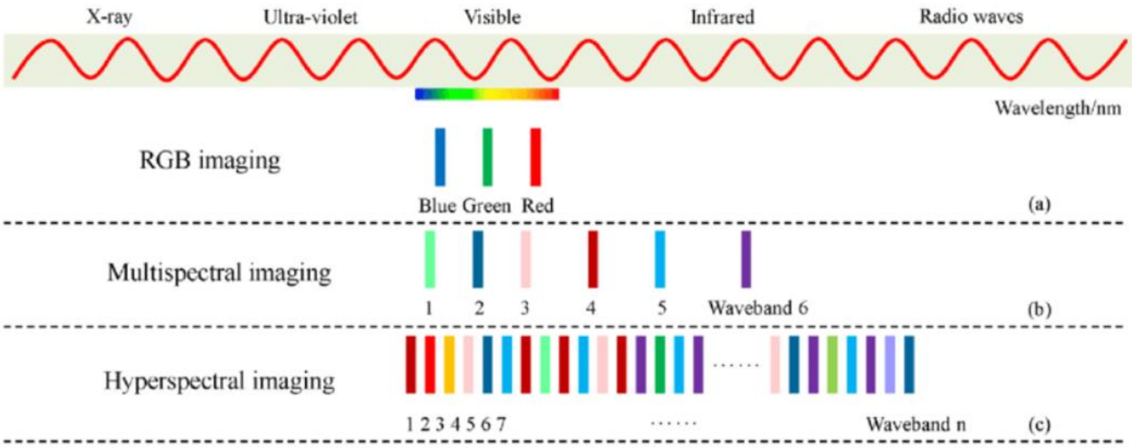

Figure 01. RGB, multispectral and hyperspectral imaging at various wavebands.

Benefits of Multispectral Sensors in Agriculture

Early Detection of Crop Stress

One of the most significant advantages of multispectral sensors is their ability to detect crop stress before it becomes visible. Subtle changes in reflectance patterns can indicate water stress, nutrient deficiencies, or disease. Early detection allows farmers to address issues promptly, minimizing potential damage and improving crop resilience.

Precision Fertilization

Multispectral sensors provide precise information about nutrient deficiencies in different parts of a field. This enables targeted fertilization, reducing the amount of fertilizer used and minimizing environmental impact. By applying nutrients only where needed, farmers can enhance crop growth while conserving resources.

Improved Pest and Disease Management

Pests and diseases often manifest as changes in plant health that multispectral sensors can detect early. By identifying these issues through changes in reflectance data, farmers can implement targeted treatments, reducing the spread of pests and diseases and decreasing reliance on broad-spectrum pesticides.

Efficient Irrigation Practices

Multispectral sensors can assess soil moisture levels and plant water needs more accurately than traditional methods. This information helps farmers optimize irrigation schedules, reducing water waste and ensuring crops receive the appropriate amount of water for healthy growth.

Recent Innovations and Applications

The integration of multispectral sensors with other technologies has significantly enhanced their utility in agriculture. Some recent developments include:

Drone Technology Integration

The use of drones equipped with multispectral sensors has revolutionized field monitoring. Drones can cover large areas quickly and provide high-resolution data, making it easier for farmers to manage extensive fields. This integration allows for detailed, real-time monitoring of crop health across diverse landscapes.

Data Analytics and Machine Learning

Recent advancements in data analytics and machine learning have improved the interpretation of multispectral data. Sophisticated algorithms can analyze complex datasets to predict crop yields, identify potential issues, and offer actionable insights. This enhanced analytical capability helps farmers make more informed decisions and improve overall farm management.

Case Studies and Real-World Applications

Precision Agriculture for Corn Crops

A study by Zhang *et al*., (2023) demonstrated the effectiveness of multispectral sensors combined with drones for monitoring corn crops. The research highlighted improvements in yield prediction and management practices, showcasing the technology's potential for enhancing large-scale agriculture.

Early Detection of Soybean Rust Disease

Thompson *et al*. (2022) investigated the use of multispectral sensors for early detection of soybean rust disease. Their study showed that multispectral imaging could identify the disease before visible symptoms appeared, leading to more effective and targeted fungicide applications.

Precision Fertilization in Wheat Crops

Miller *et al*., (2023) used multispectral imaging to detect nitrogen deficiencies in wheat crops. Their findings allowed for precision fertilization, improving crop health and reducing costs. The study highlights the role of multispectral sensors in efficient nutrient management.

Pest Detection in Vegetables

Liu *et al*., (2024) demonstrated how multispectral sensors could detect early signs of pest infestations in vegetables. The ability to identify pests early enabled more targeted pest control measures, reducing crop losses and pesticide use.

Challenges and Future Directions

Despite their advantages, multispectral sensors also face challenges. These include the high cost of equipment, the need for specialized training to interpret data, and the integration of multispectral data with other farming practices. Future advancements may focus on reducing costs, improving data interpretation tools, and enhancing the integration of multispectral sensors with other agricultural technologies.

Conclusion

Multispectral sensors are transforming crop health monitoring by providing detailed, actionable insights into plant conditions. Their ability to detect early signs of stress, optimize fertilization, manage pests and diseases, and improve irrigation practices makes them a valuable tool in modern agriculture. As technology continues to evolve, the integration of multispectral sensors with drones, data analytics, and machine learning will further enhance their capabilities, leading to more efficient and sustainable farming practices.

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