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ANTIOXIDANTS: SHIELDING THE MIND AND BODY FROM OXIDATIVE STRESS AND DEPRESSION

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Did you know that depression is one of more than 70 chronic illnesses that are exacerbated by oxidative stress? Our best line of protection against this problem may be antioxidants. Depression, another name for depressive illnesses, is a common mental illness that causes prolonged sadness, loss of enjoyment, or disinterest in activities. Approximately 280 million individuals worldwide suffer from depression, which is equivalent to 3.8% of the population, including 5% of adults. Females are more likely than males to have depression, according to current WHO reports. The National Institute of Mental Health's data on the rise in depression cases across age groups is shown in Table 1.1. These statistics emphasize the importance of addressing depression as a public health issue.

Ages (years)	2015	2020
12-17	12.7%	16.9%
18-25	10.3%	17.2%
26-34	7.5%	9.9%

Table 1.1 Depression cases across different age groups

Now imagine a free radical as a fire spark that burns and damages the environment. When there are too many sparks and not enough firefighters, oxidative stress happens. As those firefighters, antioxidants extinguish the flames before they do any damage. To put it another way, free radicals are unstable molecules with unpaired electrons. When they build up within our body, they can create oxidative stress, which can harm cells and tissues. Antioxidants, on the other hand, are chemicals that may neutralize these free radicals by giving up an electron, stopping them from harming tissues and cells. Figure 1 shows these basic terminologies.

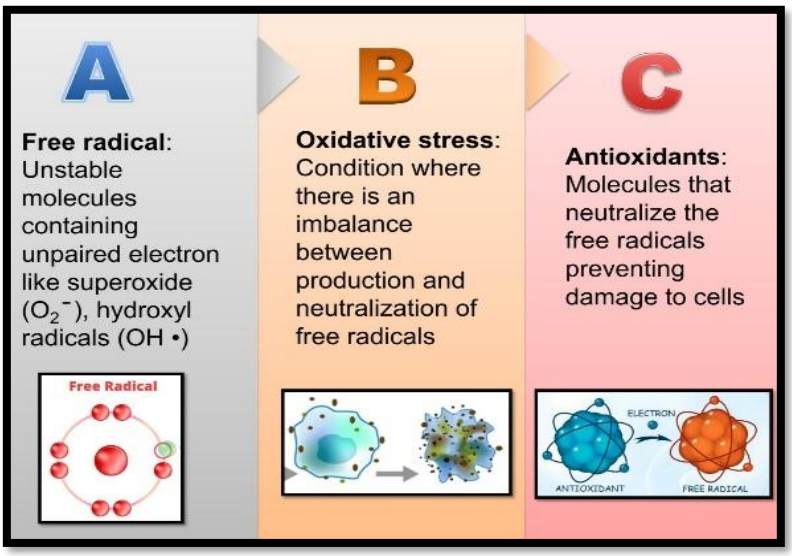

Figure 1: Definition of A) Free Radicals, B) Oxidative stress and C) Antioxidants

Oxidative stress is largely caused by Reactive Oxygen Species (ROS), which are extremely reactive substances. Although they are byproducts of regular cellular metabolism, their overproduction can cause major harm to our cells and tissues as well as play a role in the emergence of a number of illnesses, including depression, cancer, cardiovascular disease (CVD), and neurodegenerative disorders.

Before discussing about "how antioxidants act as defence system?", let's learn about "how these ROS gets produced within our body?". Our cells can autonomously manufacture ROS in the following ways:

- **During energy production:** When energy is being produced, the cell's powerhouse, the mitochondria, leak some electrons through the electron transport chain (ETC) when they create Adinosine Triphosphate (ATP) for the cell through a process known as oxidative phosphorylation. Superoxide (O_2^-), a form of ROS, can be created when these leaking electrons combine with oxygen in the body.
- **During immune response:** The immunological response also results in the production of ROS. When a foreign body, such as bacteria or a pathogen, enters our body, the immune cells' NADPH (Nicotinamide Adenine Dinucleotide Phosphate) oxidase enzyme creates superoxide, a kind of ROS, which aids in the pathogens' death during infection. However, if these ROS are generated in excess, they may harm healthy cells.
- **During Fenton reaction:** Superoxide (O_2^-) can be changed into hydrogen peroxide (H_2O_2) in the body during the Fenton Reaction by the enzyme Superoxide Dismutase (SOD). But although H_2O_2 seems harmless, when it combines with iron, it can create extremely dangerous ROS, including hydroxyl radicals (OH•), which are the most reactive of all the ROS and can seriously destroy DNA, lipids, and proteins.
- **By external sources:** Exposure to environmental elements such as pollution, cigarette smoke, poisons, and ultraviolet radiation from the sun can raise the creation of reactive oxygen species (ROS). These outside factors have the potential to weaken the body's defences against oxidative stress and damage its natural antioxidant defences.

This is how ROS gets generated within the body and can have a negative impact on the cells including damage to biomolecules (DNA or protein), cell necrosis (cell death), mitochondrial dysfunction, immune system dysregulation, chronic diseases and can even impact negatively on reproductive health.

Relevance of Depression to Antioxidants and Oxidative stress

There is a connection between depression, oxidative stress, and antioxidants. Oxidative stress occurs in the body when free radicals target healthy, normal cells. These oxidative stressors have the potential to further harm the body's neurons or brain cells, which can result in inflammation and depression symptoms. However, when antioxidants do their job, they neutralize free radicals by providing an electron, which prevents oxidative stress and, in turn, prevents depression in the individual. Figure 2 shows how free radicals can cause oxidative stress which can effect the brain cells and can cause depression.

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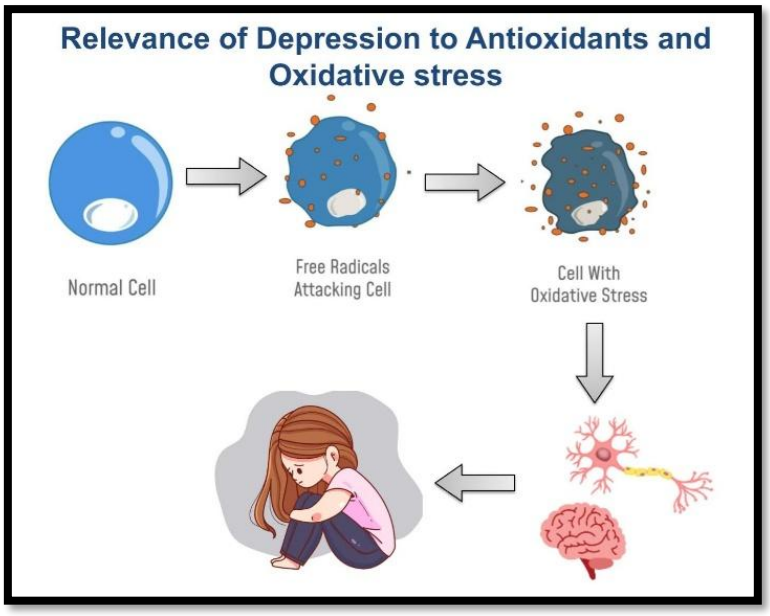

Figure 2 Relevance of Depression to Antioxidants and Oxidative stress

But do you know that **"Why this oxidative stress is more likely to occur in brain?"** The reason is due to the high oxygen demand by the brain cells to perform well. Due to this high oxygen demand, there are more possibilities of production of ROS within brain leading to oxidative stress. Along with that, brain has low level of antioxidants which results in less neutralization of ROS. Moreover, the metals like copper and iron are present in abundant amount within brain cells which can react with H_2O_2 and form radicals. Aging also becomes a factor as with increase in age, the brain's natural antioxidant defence system gets weaken.

Therefore, antioxidants are essential for reducing the rising levels of oxidative stress and depression in today's world. Because of their capacity to inhibit or slow down oxidation by eliminating free radicals, they function as therapeutic agents in the treatment of depression. They are frequently reducing substances that stop oxidative chain reactions, such as thiols or polyphenols. In the manner listed below, they serve as a defence mechanism.

- Certain processes that result in the production of ROS can be inhibited by these antioxidants. They have the ability to alter enzymes that are part of the mitochondrial electron transport chain. For example, Coenzyme Q10 and N-acetylcysteine (NAC).
- They serve as radical scavengers, giving ROS electrons and changing them into less reactive, more stable molecules. For example, Vitamin C and E.
- They can help in converting toxic radicals into the harmless molecules like water and oxygen with the help of enzymes catalase or glutathione peroxidase that converts H_2O_2 into water (H_2O) and oxygen (O_2).
- Malondialdehyde (MDA), which is produced when ROS attack lipids, intensifies oxidative damage by generating more radicals. By neutralizing ROS, antioxidants such as vitamin E and polyphenols stop this chain reaction. Additionally, glutathione detoxifies MDA.
- The body produces antioxidant enzymes like SOD, catalase, and glutathione. Certain compounds (sulforaphane) can activate pathways like Nrf2 that triggers the body to make more antioxidants.

In this way, antioxidants serve as a powerful shield against oxidative stress. By incorporating antioxidant-rich foods into our diet—such as citrus fruits, tomato juice, turmeric, ginger, cloves, garlic, mint, fenugreek seeds, amla, fennel seeds, saffron, black pepper, mulberries, walnuts, almonds, tulsi, and cruciferous vegetables—we can actively reduce stress and promote overall well-being. Nourishing our bodies with these natural protectors not only strengthens our physical health but also fortifies our mental resilience.

"In a world filled with stressors, fueling our minds and bodies with antioxidants is our best defence against the unseen enemy of oxidative stress."

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SUSTAINABLE GLOW WITH STUBBLE BURNING

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Abstract

The biggest cause of air pollution, primarily in Northern India, is stubble burning. It is a source of gaseous pollutants that seriously harm the environment and human health, including CO_2, CO, NO_3, and CH_4. Due to stubble burning that takes place after the rice harvest (October–November), India experiences the most hazardous haze during the winter months. Because of this, the majority of Indian cities—more especially, those in the National Capital Region (NCR)—face extreme pollution, frequently surpassing the dangerously high levels of the air quality index (AQI). The majority of northern Indian farmers were unaware of their potential risks, and the Indian government offered no appropriate remedy.

Introduction

One of the main issues endangering the environment and public health in northern India is stubble burning. The practice of stubble burning, which involves burning crop leftover after harvesting crops like rice and wheat, is currently prevalent in northern India, particularly in Delhi, Haryana, Punjab, and some areas of western Uttar Pradesh. Burning biomass in an open field is a well-established technique used worldwide for land clearance and land use changes to get rid of both living and dead plants. It has been estimated that humans account for nearly 90% of biomass combustion, although only a small portion of natural fires are responsible for the overall amount of vegetation burnt(Paul et. Al., 1990). Pusa 44 is the largest harmful variety but is still sown by the farmers. Stubble burning is one of the major contributors to atmospheric pollution in the world, releasing particulate and gaseous pollutants that have severe effects on human health and the environment (Sharma et al., 2010). This is the main reason that the pollutant stays longer compared to summer, which affects the atmosphere during that time, and also the rice stubble is most harmful, level effects, and increases the pollution. It was reported that the air pollution level in Delhi during October 2017 was six fold as compared to that during July of the same year. The northern region of the country has the highest rate of DALY, especially in the U.P., Punjab, Haryana, and Rajasthan, but also for the reduction of these stubble burning effects, the government also launches several schemes. The Government of India reported a reduction in the number of stubble fires in Haryana and Punjab by about 38.93% and 20.3%, respectively, as compared to 2016 (Singh, 2018).

Effect of Stable Burning

Effect on air quality

In 2001, the World Bank conducted a source apportionment study (1st of its kind) on PM2.5 for several Indian cities. They discovered that biomass burning contributes 9-28%, 23-29%, 24%, and 37-70% to the PM2.5 concentrations in Delhi, Mumbai, Chandigarh, and Kolkata, respectively.

Effect on soil fertility

It is also impacts on the soil fertility after the stubble burning it kills the microbes and nutrients due the burning. The heat from burning destruct the essential soil nutrients and microorganisms, reducing soil fertility and productivity. Stubble burning also decreases essential nutrients like

nitrogen, phosphorus, and potassium, killing beneficial soil microbes due to the high heat generated during burning, and disrupting the natural nutrient cycling process, ultimately leading to decreased crop productivity and the need for increased fertilizer usage to compensate for the lost nutrients.

Effect on agricultural productivity

Stubble burning, the practice of setting fire to crop residues after harvest, has several negative effects on agricultural productivity. Loss of beneficial soil microbes essential for nutrient cycling are destroyed. Burning depletes essential nutrients like nitrogen, phosphorus, and potassium. Around 25% nitrogen and 60% sulfur present in crop residue are lost as gases.

Effect on human health

Stubble burning is serious issue on human health due to the toxic pollutants and particulate matter into the air. Fine particulate matter (PM2.5 and PM10) from burning enters the lungs, causing breathing difficulties. Increases cases of asthma, bronchitis, pneumonia, and chronic obstructive pulmonary disease. Higher risk of lung infections, especially among children and the elders. Pollutants like carbon monoxide (CO) and nitrogen oxides (NO_3) reduce oxygen levels in the blood, increasing the risk of heart attacks and strokes. Long-term exposure can lead to high blood pressure and arterial blockages. Smoke exposure causes burning, redness, and watering of the eyes. Skin irritation and allergies increase due to prolonged exposure to airborne.

Wealthy solutions

Waste to wealth solutions, if conducted on a larger scale, offer a tremendous opportunity to transform India into a sustainable agriculture economy. The Indian government, for instance, has started several initiatives to produce bio energy out of crop residue, including the setting up of bio-ethanol plants in Haryana and Punjab. However, there needs to be a clear cut strategy to overcome several hurdles. The biggest ethanol plant in Punjab has already been delayed twice, while another ethanol plant in Punjab has been called off following a community protest over alleged environmental violations. Although the central government has sought to establish several bio ethanol plants, the weak coordination between state and center makes it difficult.

There are some suggestions are :

Smog Tower and Cloud Seeding

Studies reveal that the drawbacks of a smog tower and cloud seeding outnumber the benefits, given that they are expensive to carry out. Thus, there is an urgent need for innovation to make them cost-effective. Although the Delhi government sought to conduct artificial rain to curb the capital's rising pollution, it was denied permission by the central government.

New Proposed Crop Variety

Farmers complain that the PR 126 variety, which has been suggested as a better alternative to PUSA 44, has low yields and crop defects such as broken grains. It is thus imperative to improve quality using scientific technologies such as genome editing.

Industrial Uses

It is my personal idea and also in some places also following that we have use the stubble as making Bowls by replacing the paper bowls. First we take a stubble than put into the water for 1-2 days When they become the soft put outside the water. Then put the stubble into bowl making Machines and our bowls will ready. It helps in to reduce the deforestation and making economic benefits also to the farmer.

Conclusion

The large-scale rice-wheat crop rotation system practiced in India has resulted in the generation of a significant quantity of crop stubble, often more than the quantity of grains harvested. It may be concluded that the combined effects of stubble burning emissions and meteorological conditions are the cause of the severity of air quality, especially during rice stubble burning episodes in north Indian cities. The pollutants from stubble burning pose a grave risk to the health of the exposed population as they are linked to several health issues and even death in severe cases. In addition to atmospheric pollution, stubble burning may also lead to climate change, global warming, and the destruction of soil nutrients. It is, therefore, the need of the hour to implement exhaustive policies to curb this menace at its base. Laws such as the Preservation of Subsoil Water Act 2009 and welfare schemes such as the MSP crop list need to be reviewed

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THE GROWING INFLUENCE OF INDIA'S AGRICULTURE IN SHAPING THE GLOBAL FOOD LANDSCAPE: STRENGTH, SETBACKS, SUSTAINABILITY AND WOMEN'S ROLE

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ABSTRACT

India's agriculture forms the backbone of its economy and global food security, contributing significantly to the production and export of staple crops like rice and pulses, as well as dairy. Its thriving horticulture sector, which includes fruits, vegetables, and spices, further strengthens its position in global markets. Horticultural crops such as bananas, mangoes, onions, and potatoes have experienced remarkable growth, surpassing food grain production and enhancing India's agricultural diversity. With vast arable land and a strong workforce, India has established itself as a key player in global agriculture. However, challenges such as water scarcity, excessive fertilizer use, and gender disparities in land ownership hinder sustainable growth. This article explores India's agricultural strengths, its global influence, and the urgent need for modernization and sustainability to secure its future role in the global food system.

Introduction

India's agriculture is more than just a livelihood—it's a lifeline for over 1.4 billion people. Rooted deep in the country's economy, it influences global food security and trade. As highlighted in the *FAO Statistical Yearbook 2024*, India has consistently maintained its position as one of the top agricultural powers, contributing not just to domestic food supply but also shaping the future of global farming (**FAO, 2024**).

This article takes a closer look at India's agricultural strengths, the hurdles it faces, and the promising path forward as the country continues to evolve on the world stage.

India's Global Footprint in Agriculture

India's agricultural dominance isn't just about size; it's about scale, efficiency, and diversity.

- **Horticulture Powerhouse:** India's horticulture sector continues to cement its global presence; producing 334.60 million tonnes (MT) in 2020-21, surpassing food grain production and contributing to 33% of the country's agricultural output. This consistent growth has positioned India as a leader in fruit, vegetable, and spice production, ensuring a steady supply of nutritious food both domestically and internationally (MoAFW, 2022).
- **Dominance of TOP Crops:** India's Tomato, Onion, and Potato (TOP) crops form the backbone of its horticultural industry, accounting for 31% of total horticulture production. In 2020-21, India produced 21.18MT of tomatoes, 26.92MT of onions, and 56.17MT of potatoes, supporting both domestic consumption and a thriving export market. Onions and potatoes, in particular, are integral to India's food security and are widely exported, strengthening India's role as a global supplier of essential vegetables (MoAFW, 2022).

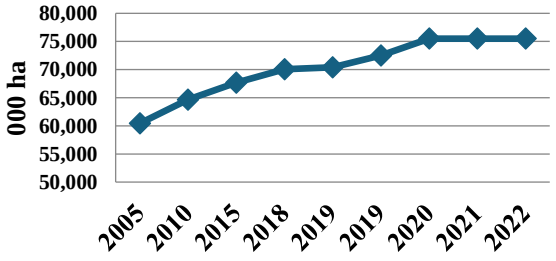
- **A Global Fruit Basket**: India remains the world's largest producer of banana, mango, papaya and okra, with banana production alone surpassing 33MT annually. These crops are widely consumed across international markets, with mangoes and bananas leading India's fresh fruit exports. Andhra Pradesh, Maharashtra, and Uttar Pradesh dominate fruit production, ensuring a robust supply to both domestic and international markets (MoAFW, 2022).
- **Flourishing Floriculture Industry**: The floriculture industry in India is rapidly growing, catering to both domestic demand and international exports. In 2020-21, India produced 3.19MT of flowers, with Tamil Nadu (521,000t), Karnataka (503,000t), and Madhya Pradesh (413,000t) emerging as the leading flower-producing states. The country's diverse floral offerings, including roses, marigolds, and orchids, are increasingly in demand for ornamental, religious and medicinal purposes worldwide (MoAFW, 2022).
- **Spicing Up Global Markets:** India dominates the global spice market, producing over 75% of the world's turmeric, chili, black pepper, and other spices. This unparalleled production ensures India remains the largest producer and exporter of spices, meeting the diverse culinary and medicinal needs of nations across the world (MoAFW, 2022).
- **Growing Horticultural Exports**: Horticultural exports continue to expand, with grapes leading the segment at 247,000t, valued at ₹2,30,208 lakh. Other key exports include bananas, mangoes, and onions, reinforcing India's position as a global supplier of fresh and processed horticultural products (MoAFW, 2022).
- **Feeding the World**: India's rice production alone hits 130 MT annually, securing its place as the world's leading exporter, contributing to 40% of global rice exports (FAO, 2023). India is also the largest producer of pulses, with 27MT grown each year, meeting the dietary needs of millions globally (**World Bank, 2024a**).
- **Dairy Giant**: At the heart of India's agriculture is dairy farming, with 226MT of milk produced in 2022. This makes India the largest producer of milk, a testament to the economic and cultural importance of dairy to the nation (**DES, 2025**).
- **Arable Land and Cropping**: With 157 million hectares of cropland—11% of the world's total—India's agricultural land is vast, though its cropland per capita, at just 0.12 hectares, remains well below the global average of 0.20 hectares. This efficiency is crucial in feeding such a large population (**World Bank, 2024b).**

These achievements reflect not only India's ability to produce enough for its people but also its significant role in ensuring food security worldwide.

Irrigation and Water Challenges

India's irrigation systems are some of the largest in the world, serving 76 million hectares (**FAO, 2024**). Over time, India's irrigation infrastructure has seen consistent growth, from 60,432 thousand hectares in 2000 to 75,500 thousand hectares from 2020 to 2022 (FAO, 2024). This is a critical factor in maintaining crop productivity, especially for water-intensive crops like rice and sugarcane. However, this reliance on irrigation comes with challenges:

Fig 1. India's Area under Irrigation (000 Ha)

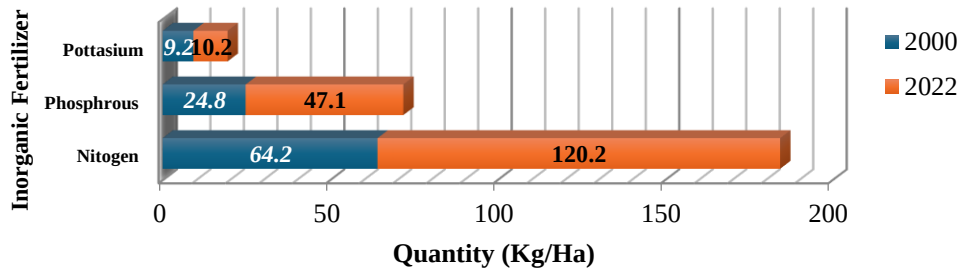


- **Water-Intensive Crops**: Rice and sugarcane are the pillars of India's irrigated agriculture but also the biggest water users. As much as 70% of India's agricultural water comes from groundwater sources—raising significant concerns about sustainability (FAO, 2024).
- **Efficiency Innovations**: To counter this, India must look to modernize its irrigation practices. Drip irrigation; for example, can save up to 50% of water, while enhancing crop yield. Technologies like these could not only alleviate the water crisis but also boost agricultural productivity across regions.

By embracing water-efficient practices, India can ensure that its crops continue to thrive without compromising precious water resources.

Fertilizer Use: Boosting Yields at a Cost

Fig 2. Inorganic Fertilizer Use per Cropland Area by Nutrient (KG per Ha)



India's dependence on fertilizers is a serious issue. On one hand, they've significantly boosted yields. On the other, their overuse has caused environmental damage:

- **Fertilizer Consumption**: India's fertilizer consumption of 150 kg per hectare is higher than the global average of 113 kg. The heavy use of nitrogen fertilizers—accounting for 58% of total fertilizer consumption—has led to soil degradation and pollution in rivers and lakes (FAO, 2024).
- **Soil and Water Concerns**: Excess fertilizer use contributes to soil erosion and water contamination. However, it's not just India facing this issue. Major agricultural players like Brazil, the U.S., and Russia are also grappling with similar environmental costs (FAO, 2024).

By exploring organic farming, precision agriculture, and reducing fertilizer dependency, India can move toward a more sustainable, less resource-draining future.

Women and Agriculture: A Growing Force

Agriculture continues to be a major source of employment in India, with 226 million people engaged in agricultural activities, accounting for 26% of the country's workforce in 2022. While this is a significant portion, it reflects a decline from 40% in 2000, a trend similar to many other countries as labor shifts toward industry and services. This shift in labor indicates broader economic changes but also underscores the continued importance of agriculture in providing livelihoods, especially in rural areas.

Global Overview of Women in Agriculture

As of 2022, women constitute 38.5% of the global agricultural workforce. This participation rate varies significantly by region, influenced by socio-economic, cultural, and technological factors: (FAO, 2024).

Africa: The highest female participation in agriculture is observed in Africa, where women account for 44.4% of the agricultural workforce. This is largely due to subsistence farming, where women play a crucial role in producing food for household consumption and local markets. Countries like Rwanda (61%), Mozambique (58%), and Malawi (55%) have high female participation in agriculture, often influenced by cultural norms that assign agricultural work predominantly to women.

Asia: In Asia, women represent 37.3% of the agricultural workforce, with notable contributions in South and Southeast Asia. India, with a population of over 1.4 billion, shows that women's role in agriculture is growing, though significant challenges remain. Female participation in agriculture has increased from 32.8% in 2000 to 36% in 2022, underlining a trend toward increased involvement of women in food production, especially in rural areas.

Europe: Europe has a slightly lower participation rate of 35.2% due to industrialized farming techniques, which require less labor. Northern and Western Europe show lower rates, as the agricultural sector there is highly mechanized.

Americas: In North and South America, women make up 23.3% of the agricultural workforce, a lower percentage due to the prevalence of mechanized farming systems. However, women's roles in small-scale and family-owned farms, particularly in Central and South America, remain crucial.

Women in Agriculture in India

In India, women account for about 36% of the agricultural workforce, an increase from 32.8% in 2000. However, women face significant challenges, particularly in terms of land ownership, access to credit, and income disparity (MoAFW, 2021).

Key Statistics on Women in Indian Agriculture:

Land Ownership: Despite their high participation in agriculture, women own less than 15% of agricultural land in India, indicating a significant gender gap in land ownership. This is critical since land ownership is linked to access to resources, loans, and agricultural programs.

Economic Contribution: According to the Agriculture Census 2015-16, women operate around 11.72% of the total agricultural land in India. This figure highlights the substantial role women play, though they still remain marginalized in terms of land ownership.

Wage Gap: In India, women in agriculture face a 20-30% wage gap compared to their male counterparts. The gap is even more pronounced in rural areas, where women have less access to formal employment opportunities and are often paid lower wages for similar work.

Gender-Sensitive Programs: According to the Situation Assessment Survey of Agricultural Households 2019, while many programs exist to support farmers, women are still underrepresented in agricultural extension services, which limit their access to modern farming techniques and technologies. As per the data, nationwide, only 15.6% of female farmers were enrolled under PMFBY during the 2020-21 period. Among the states, Kerala shows a higher female enrollment of 31.8%, followed by Puducherry at 32.7%, and Sikkim at 35.7%. However, participation is notably low in states like Punjab and Bihar. In PM-KISAN, the percentage of female beneficiaries is also limited, with an overall national participation of 25.1%. States like Lakshadweep (49.4%), Manipur (54.2%), and Kerala (44.3%) report higher female beneficiary rates, while states like Punjab (0.1%), Jammu & Kashmir (11.2%), and Madhya Pradesh (21.3%) show very low numbers.

Economic Impact of Women in Agriculture in India

The economic contribution of women in agriculture is significant but often undervalued:

Income Disparity: According to Agricultural Household Income Statistics (2019), the average monthly income for agricultural households in India varies significantly across regions. For example, women in Andhra Pradesh earn around ₹10,480 per month, whereas women in Himachal Pradesh earn ₹12,153, reflecting the regional disparity in agricultural productivity and income.

Wage Gap: Women generally face a lower income compared to men. The monthly income of male-headed agricultural households is often higher than that of female-headed households. In states like Uttar Pradesh, Madhya Pradesh, and Bihar, women face a significant income disparity, limiting their ability to access resources and achieve financial independence.

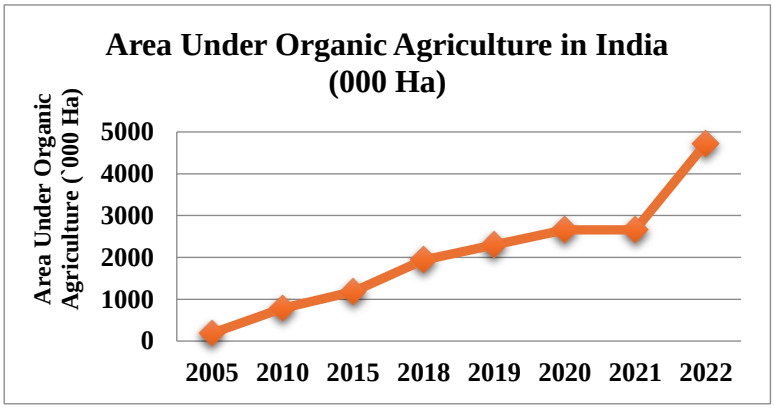
Women in agriculture face major barriers, including limited land ownership, restricting their access to credit, technology, and government schemes. They also lack access to knowledge and technology, as many are excluded from training programs, impacting productivity. Limited financial support further hinders investment in better farming practices, despite schemes like PM-KISAN. Additionally, cultural norms confine women to unpaid labor, limiting their decision-making power.

To empower women, land reforms should ensure ownership rights, enabling access to resources. Gender-focused training can enhance skills, while financial inclusion through loans and subsidies can boost investment. Equal pay policies and greater female representation in decision-making bodies are essential for a more inclusive agricultural sector.

Green Revolution in Sustainability

India's agricultural future hinges on its ability to embrace sustainability. The country is already on the right path with initiatives aimed at reducing environmental impacts: (FAO, 2024)

- **Organic Farming**: With 2.3 million hectares dedicated to organic farming, India has become one of the world's leading producers. The growth in organic farming from just 185,000 hectares in 2005 reflects the increasing global demand for clean, health-conscious products.



- **Climate Action**: Agriculture in India contributes significantly to greenhouse gas emissions, with 650MT of CO_2 produced annually—largely due to livestock and rice cultivation. Reducing emissions through methane-reduction technologies and adopting climate-resilient crops will be crucial in mitigating climate change impacts.

Fostering sustainable practices will ensure that India can feed its population and protect the environment for generations to come.

Trade: Strengthening Global Influence

India's agricultural exports contribute significantly to its economy, but there's room for improvement in leveraging this potential: (FAO, 2024)

- **Export Success**: India is the largest exporter of rice and contributes 75% of the world's spice supply. In 2022, agricultural exports were valued at $50 billion, demonstrating India's strong presence on the global stage.

- **Import Dependency**: However, India still depends on imports for crucial items like edible oils, fertilizers, and pulses. Edible oil imports alone account for 60% of the country's consumption, indicating vulnerabilities in India's agricultural self-sufficiency.

To strengthen its export profile, India must focus on improving infrastructure, enhancing product quality, and reducing logistical bottlenecks that hinder growth.

A Future Built on Strengths and Innovation

Despite its challenges, India's agricultural sector is rich in potential. The country's vast crop diversity, strong community-based farming traditions, and massive agricultural workforce offer a solid foundation for future growth:

- **Diverse Agro-Climatic Zones**: India's varied climate zones allow it to produce everything from staple crops like rice and wheat to cash crops like sugarcane and cotton, as well as niche products like spices and medicinal plants.
- **Farmer Networks**: Community-driven initiatives like farmer producer organizations (FPOs) and self-help groups have proven effective in facilitating knowledge-sharing and market access for smallholder farmers.
- **Workforce Strength**: With 226 million people working in agriculture, India's large labor force continues to be a driving force behind its farming success.

By harnessing these strengths and implementing modern techniques, India can continue to be a leader in global agriculture.

Path Forward: Key Priorities for Progress

To ensure sustained growth, India's agricultural sector must focus on these key areas:

1. **Modernizing Practices**: Mechanization and technology adoption are critical for boosting productivity and reducing the labor burden on farmers.
2. **Water Efficiency**: Investments in irrigation technologies, such as drip and sprinkler systems, can mitigate water usage and enhance crop yields.
3. **Inclusive Growth**: Empowering women with land rights, financial independence, and access to modern tools can unlock immense potential in rural India.
4. **Sustainability**: Shifting toward organic farming, precision agriculture, and methane-reduction techniques will help reduce environmental damage.
5. **Export Competitiveness**: Enhancing infrastructure, meeting global quality standards, and diversifying export products will boost India's trade influence.

Conclusion: Shaping Global Agriculture

India's agricultural sector is at a crossroads, with its strengths serving as a solid foundation for the future. By addressing environmental challenges, embracing innovation, and focusing on inclusivity, India has the potential to not only meet the needs of its population but also lead the world in sustainable agricultural practices. India's agricultural influence will continue to grow, shaping global food security and sustainability trends for years to come.

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MAIZE REVOLUTION: KEY MILESTONES IN CROP DEVELOPMENT

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Abstract
Maize in India, like in many parts of the world, has gained increasing importance in recent years due to rapid urbanization, environmental concerns, and the growing recognition of the numerous benefits provided by maize. Addressing the origin of maize and key milestones in its development requires a thorough knowledge. This article explores the role of maize revolution in world as well as in India including its origin and dissemination around the world. The review study also highlights how this trend of maize revolution can address broader socio-economic issues of the past, food security, and environmental sustainability. There has been progress in some areas, production and productivity of maize with the cultivation of high yielding hybrids. Moreover, several government initiatives and policies are also helping shape the future of maize in India.

Introduction
Maize (*Zea mays* L.) , also known as corn, is a tall stout grass that produces cereal grain. Globally, it is also known as queen of cereals due to its highest yield potential, diversified use as food, feed, and industrial uses. It is grown on 205.9 million hectares of land worldwide, producing 1210.2 million tonnes of grain with an average yield of 58.8 q/ha (FAO, 2022). Now, with a 9.9-million-hectare area, 31.7 million tonnes of production, and an average grain yield of 31.2 q/ha, it is the third most important cereal crop in India after rice and wheat (FAO, 2022).

History of maize and its origin: It was domesticated by indigenous peoples in southern Mexico about 9,000 years ago from wild teosinte. The kernels of *teosinte* were small and dispersed, but through careful cultivation, larger and more compact kernels were selected, marking the first step in maize's transformation. Early agricultural developments started during 1000 CE – 1500 CE played a central role in Mesoamerican economies by spreading it across America and later on becoming a staple crop in a variety of cultures. After that, as societies in North and South America progressed, they improved maize farming methods and created different kinds of maize for various climates and environments. The crop was grown in diverse environments, from the highlands of the Andes to the lowlands of Central America. Varieties of maize were cultivated for different purposes, such as food, ceremonial use, and animal fodder. In post Columbian Era, with the arrival of Europeans in the Americas in 1492 CE maize was introduced to Europe and other parts of the world including Asia. It quickly became a global crop, adapting to new environments and influencing diets around the world and became a staple crop in many countries including Italy, Spain and later United States. It is widely cultivated in parts of China in Mid-16th Century. In 16th Century, Portuguese traders are considered the most likely source of maize introduction to India. Maize becomes established in India, spreading across different regions during 17th Century. Scientific advancements started during 18th and 19th Century (1700s- 1800s) when Europeans settlers began experimenting with different farming techniques to improve maize yield. Beal (1880) was the first to propose commercial cultivation of intervarietal hybrids. In mid 1800s agricultural revolution introduced more

advanced farming techniques, such as crop rotation and new irrigation techniques, contributed to increase in maize production.

In 20th century, the development of hybrid maize greatly increased its yield. Scientists in the U.S. began developing hybrid maize varieties to increase yields, disease resistance, and drought tolerance. These hybrids were produced by cross-breeding different strains of maize with desirable traits. Shull (1909) gave the 'pureline method of corn breeding', which involved the development of inbred lines and commercial single cross (inbred x inbred) hybrids. However, there was no good response as inbred lines were weak and there were problems in commercial seed production of single cross hybrids. Jones (1918) suggested the commercial cultivation of double cross (single cross x single cross) hybrids, and their commercial use began in 1922. In 1930s, corn cultivation was transformed by the creation of hybrid maize, which was led by experts such as Henry A. Wallace. Among various types of hybrids, single crosses have the highest yield potential, uniformity and resistance against major biotic and abiotic stresses. The maize breeders, particularly in North America continued their efforts to develop vigorous inbred lines so as to make seed production of single cross economically viable. The cultivation of single crosses started in late 1950s and early 60's, and at present almost entire area in the USA is covered by single cross hybrids. The widespread use of chemical fertilizers and pesticides during 1940s-1950s allowed for further increase in maize production and productivity.

Key milestones of maize in India: In India, the maize improvement work was earlier largely confined to the State Departments of Agriculture. During 1940s and early 50s, the work basically involved isolated efforts on mass selection in local varieties in Punjab, Uttar Pradesh, Bengal and Central Provinces. These varieties were evaluated and the seeds of promising ones were multiplied and distributed to the farmers. The cultivars that were released included KT 41 in Uttar Pradesh, Basi in Rajasthan, Pusa Yellow in Bihar and Farm Sumeri in Gujarat. Initial efforts to improve maize varieties begin with the establishment of the AICMIP in 1957. This initiative played a crucial role in maize improvement through multidisciplinary coordinated breeding programs, leading to the development of high-yielding hybrids and composites. With the establishment of the coordinated project, a large number of germplasms including inbred lines were introduced from USA and Caribbean region and many locals were collected; and large-scale inbreeding was initiated in the promising introduced and indigenous germplasm. The inbred lines were crossed with varietal testers to produce top-crosses (inbreds x OP populations) which were evaluated in multilocation trials along with indigenous and exotic checks. As a result, 28 inbred lines were identified and used in hybrid breeding. The first set of hybrids was released in 1961. These were Ganga I, Ganga II, Deccan and Ranjit, and all these were double crosses. For economical seed production, a short-term approach of developing non-conventional hybrids, namely double top-crosses (single cross x non-inbred parent) was adopted. As a result, in 1963, two double topcross hybrids (Hi-starch, Ganga Safed 2) were released. The National Seeds Corporation was established in 1963 to facilitate hybrid maize seed production. However, due to less than expected impact of these hybrids and the problems faced in their seed production, the breeding strategy was reassessed, and composite breeding was prioritized. In 1967, six composites (Amber, Jawahar, Kisan, Vijay, Vikram, Sona) were released in the country. First three-way hybrid, Trishulata, was released for general cultivation in 1991 and first single cross, Paras, in 1995. These were followed by release of many other single cross hybrids like Pusa Early Hybrid Makka 1 and 2, Parkash, Sheetal and Buland. Up to 1972, twenty-one late maturing cultivars were released. The production increased from 1.73 to 11.1 million tonnes and productivity from 547 to 1920 kg/ha during 1950-51 to 2002-03.

Maize for enhanced nutritional quality in India: Thereafter research focused on enhancing the nutritional value of maize, such as increasing its vitamin and mineral content (e.g., "quality protein maize" or QPM, which has higher levels of lysine and tryptophan) and Provitamin A, carotenoids, Fe and Zn rich maize). In spite of several important uses, maize has an in-built drawback of being deficient in two essential amino acids, *viz*., lysine and tryptophan. This leads to poor net protein utilization and low biological value of traditional maize genotypes. To overcome this problem, the maize breeders have developed quality protein maize (QPM) by incorporating opaque-2 mutant gene, which is particularly responsible for enhancing lysine and tryptophan content of maize endosperm protein. The QPM research was initiated long back during 1970's, but it gained momentum during 1990's with continuous breeding efforts on development of high yielding hard endosperm modified opaque-2 maize germplasm by International Centre for Maize and Wheat Improvement (CIMMYT) and made it available for use in the breeding program all over the world. In India, these germplasm accessions received from CIMMYT, Mexico were tested at different centers of All India Coordinated Research Project on Maize (AICRPM). Through acclimatization and repeated selection, hard endosperm modified opaque-2 maize inbred lines and their crosses have been identified for better protein quality and higher yield potential. The Directorate of Maize Research (DMR) now known as IIMR, New Delhi developed first QPM Composite variety, Shakti-1 with 0.63% tryptophan in the year 1997, which was released and recommended for general cultivation by Indian farmers in 1998. The QPM research gained further momentum by launch of National Agricultural Technology Project (NATP) on QPM in 1998 by the Indian Council of Agricultural Research (ICAR). In this project, a multi-disciplinary team of multi-institutes involving DMR, New Delhi, Punjab Agricultural University (PAU), Ludhiana, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Karnal, Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad, and Rajendra Agricultural University (RAU), Pusa wherein the QPM germplasm received from CIMMYT was acclimatized to suit the local agro-climatic conditions in India. The lines were evaluated for their productivity and deployed in combination breeding which led to release of first QPM three-way cross hybrid, Shaktiman-1 by RAU, Pusa during 2001 followed by release of first QPM single cross hybrid, Shaktiman-2 during 2004 for their cultivation in Bihar state. In 2005, CCS HAU, Karnal released another QPM single cross hybrid, HQPM-1 which is the first yellow grain QPM single cross hybrid released for its cultivation across the country. Later in the series of QPM, Shaktiman-3 and Shaktiman-4 were released by RAU, Pusa during 2006 for their cultivation in Bihar. In 2007, another QPM single cross hybrid, HQPM-5 from CCSHAU, Karnal was released for its cultivation across the agro-ecologies of India. Further, two new single cross QPM hybrids i.e. HQPM-7 from CCSHAU, Karnal and Vivek QPM-9 from Vivekanand Parvatiya Krishi Anusandhan Shala (VPKAS), Almora has been released during 2008. Vivek QPM-9 has a unique distinction of the first molecular marker assisted (MAS) converted product of normal hybrid Vivek-9. In view of combatting with malnutrition, a CRP project on biofortification in maize was initiated in 2014 in India. Under this project various QPM hybrids *viz*., Pusa HM4 Improved, Pusa HM8 Improved, Pusa HM9 Improved hybrids were also released by ICAR-IARI, New Delhi and CCSHAU, Karnal. Later on, in 2020 various QPM hybrids were also fortified with provitamin A *viz*., Pusa VH 27 Improved, Pusa HQPM 5 Improved, Pusa HQPM 7 Improved were released by ICAR-IARI, New Delhi in collaboration with VPKAS and CCSHAU, Karnal.

The development of genetically modified (GM) maize began in the 1990s, introducing traits like insect resistance and herbicide tolerance. The most notable GM maize types include Bt corn, which contains a gene from the bacterium *Bacillus thuringiensis* to protect against certain insect pests

(e.g., the European corn borer), and Roundup Ready corn, which is tolerant to the herbicide glyphosate, allowing farmers to control weeds more easily. The researchers continuing to develop new technologies and techniques to improve its yield, disease resistance, and nutritional content. In India, from 2001 to 2024, one hundred forty-four single cross hybrids have been released from ICAR-IIMR, SAUs and other ICAR institutes.

New Initiatives for maize: Apart from this, maize has been considered as a future crop which would be used as biofuel to reduce the import of petroleum products. More recently Government of India took initiative for promoting maize as a source of bioethanol. For this, a project named as "Enhancement of Maize Production in Catchment Area of Ethanol Industries' was initiated in 2024-25 by ICAR-IIMR, Ludhiana with SAUs and various ICAR institutes to enhance production and productivity of maize. Under this project various training/awareness/ exposure programme are being conducted by Indian Council of Agricultural Research (ICAR)- Indian Institute of Maize Research (IIMR) in collaboration with its partner institutes to make the maize crop profitable. Currently there is a need to work on the potential of maize in terms of increased area, productivity and productivity with the development and use of high yielding hybrids.

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FOOD SAFETY AND STANDARDS AUTHORITY OF INDIA (FSSAI) EVALUATES AND REGULATES THE COUNTRY'S FOOD SAFETY AND SECURITY

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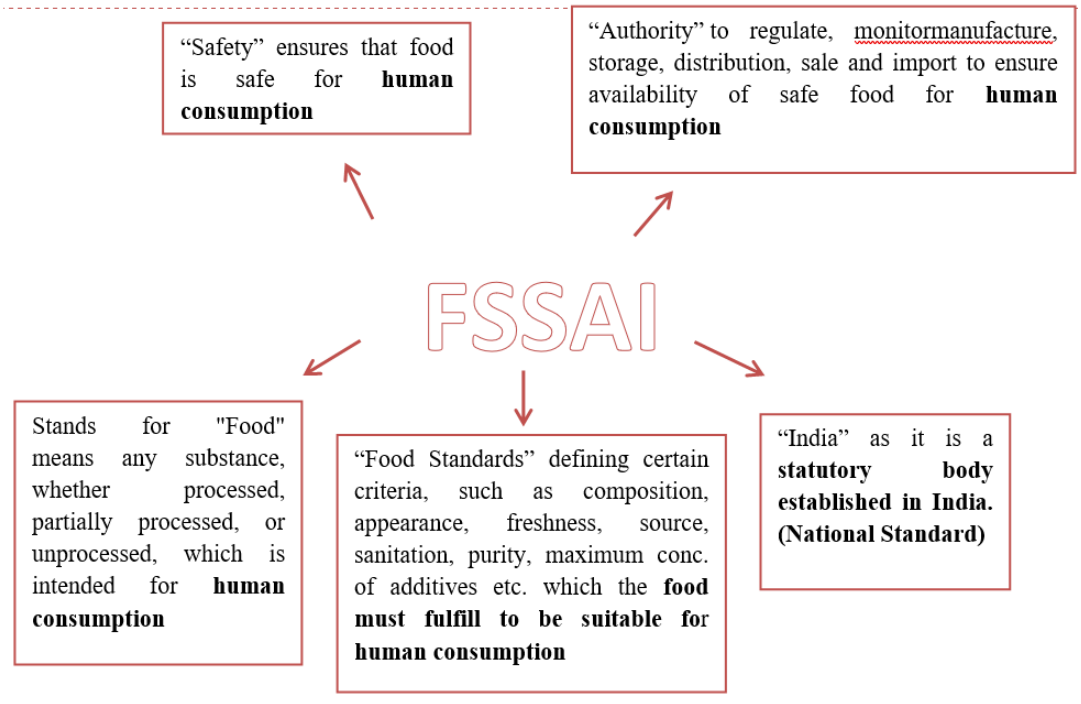
Abstract

India faces significant challenges in ensuring food safety and security due to rapid urbanization and population growth. Food quality may be compromised at various stages of the supply chain, from farm to table, through excessive pesticide use, antibiotics, toxic waste, and harmful additives. To regulate food safety, the Food Safety and Standards Authority of India (FSSAI) was established under the Food Safety and Standards Act, 2006. While FSSAI has made considerable progress in implementing food safety measures, further efforts are needed to strengthen regulatory enforcement.

Keywords : FSSAI, Food Safety, Safe, Challenges, initiatives

Introduction

Food Safety and Standards Authority of India (FSSAI) is an autonomous statutory body established under the **Food Safety and Standards Act, 2006** (FSS Act). This includes proper methods of handling, processing, and storage to reduce the risk of foodborne illnesses. Due to globalization, rapid population growth, and increasing urbanization, India encounters multiple obstacles in ensuring food safety.



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KEY POINTS	
Establishment	2008
Effectively began in	5th August 2011
Formed under the Act	Food Safety & Standards Act 23rd August, 2006
Administered under	Ministry of Health & Family Welfare
Headquarter	New Delhi
Official Website	www.fssai.gov.in
Logo	fssai

The Food Safety and Standards Act 2006 (FSSA) states:

"An Act to consolidate the laws relating to food and to establish the FSSAI for laying down science-based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import, to ensure availability of safe and wholesome food for **human consumption** and for matters connected therewith or incidental thereto."

The FSSAI maintains and supervises food safety in India. The organization plays a vital role in setting standards and regulations for various FBOs (Food Business Operators) across India.

1. Granting License – To pursue any food related business, the owner needs to get a certificate and license with the permission of FSSAI.

The licensing and registration procedure and requirements are regulated by **Food Safety & Standards (Licensing and Registration of food Business) Regulations, 2011**

FSSAI Central Licence	FSSAI State License
Required by Business owners like exporters, operators dealing with food items in central governmental agencies, airports, railways etc.	Required by medium-sized FBOs (manufacturers, individuals, or organizations that are involved in storage, those in the retail business, distributers etc.
For FBOs who have an annual turnover (gross revenue/ total sales) of **more than 20 crores**	The turnover of these **FBOs lies between 12 lakhs to 20 crores**
Operative in more than one state.	Operative at the state level only.

The license obtained is valid for a minimum of 1 year and a maximum of 5 years (*https://www.fssai.gov.in/upload/uploadfiles/files/Licensing_Regulations.pdf*)

2. Setting Rules and Regulations – Need to be followed by all food manufacturing companies, keeping into consideration hygiene and food safety.

- FSSAI has drafted **6 principal regulations** through extensive consultation with various stakeholders. These regulations have been notified in the gazette of India on **1st August, 2011** and came into force on **5th August, 2011.**

26 Regulations listed below:

1	FSS (Licensing and Registration of Food Businesses) Regulation, 2011	14	FSS (Approval for Non-Specified Food and Food Ingredients) Regulations, 2017.

2	FSS (Food Product Standards and Food Additives) Regulation, 2011	15	FSS **(Recruitment and Appointment) Regulations, 2018**
3	FSS (Prohibition and Restriction on Sales) Regulation, 2011	**16**	FSS **(Alcoholic Beverages) Regulation, 2018**
4	FSS (Packaging and Labelling) Regulation, 2011	**17**	FSS **(Fortification of Food) Regulation, 2018**
5	FSS (Contaminants, Toxins and Residues) Regulation, 2011	**18**	FSS **(Food Safety Auditing) Regulation, 2018**
6	FSS (Laboratory and Sampling Analysis) Regulation, 2011	**19**	FSS **(Recognition and Notification of Laboratories) Regulation, 2018**
7	FSS **(Salary, Allowances and Other Conditions of Service of Officers and Employees) Regulations, 2013**	**20**	FSS **(Recovery and Distribution of Surplus food) Regulation, 2019**
8	FSS(Food or Health Supplements, Nutraceuticals, Foods for Special Dietary Uses, Foods for Special Medical Purpose, Functional Foods and Novel Food) Regulations, 2016	**21**	FSS **(Safe food and balanced diets for children in school) Regulations, 2020**
9	FSS **(Transaction of Business and Procedure for the Scientific Committee and Scientific Panel) Regulations, 2016**	**22**	FSS **(Foods for Infant Nutrition) Regulations, 2020**
10	FSS (Food Recall Procedure) Regulation, 2017	**23**	FSS **(Labelling and Display) Regulations, 2020**
11	FSS **(Organic Food) Regulation, 2017**	**24**	FSS **Vegan Foods) Regulations, 2022**
12	FSS (Import) Regulation, 2017	**25**	FSS **(Ayurveda Aahara) Regulations, 2022**
14	FSS(Food Products Standards and Food Additives) 3rd Amendment Regulations, 2017	**26**	FSS **(Financial) Regulations, 2023**

FSSAI Regulations. (n.d.). Retrieved March 30, 2023, from https://fssai.gov.in/cms/food-safety-andstandards-regulations.php

3. Form the Standards of Food

- As per Food Safety and Standards (Licensing and Registration of Food Businesses) Regulation, 2011.
- All FBOs has to ensure carry out confirmatory tests, if required, and also for developing standard protocols, maintenance of referral material, training etc. in accordance with FSS Regulations as frequently as required on the basis of **risk assessment**.
- Ensuring production and delivery of safe food through their own or NABL (**National Accreditation Board for Testingand Calibration Laboratories**) accredited/FSSAI notified labs at **least once in six months.**

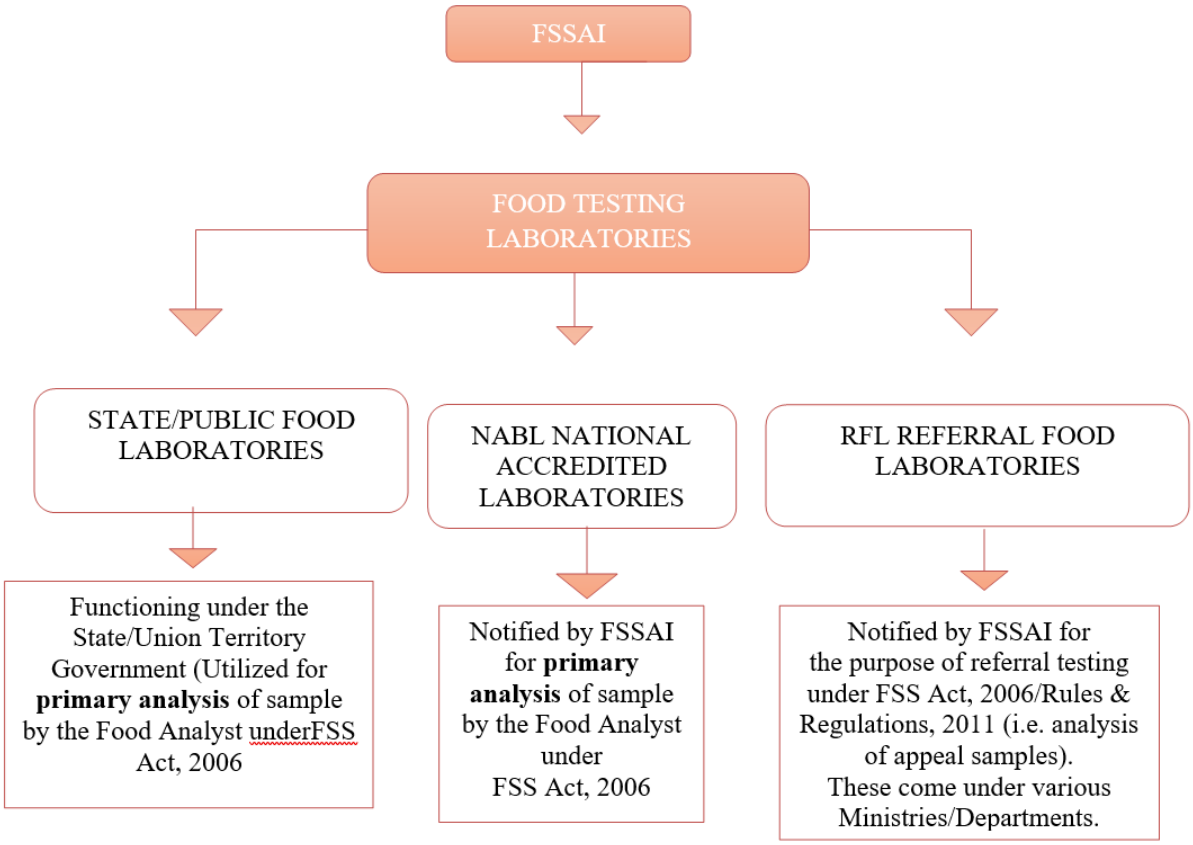

Fig. 2 Schematic showing the framework of regulatory testing laboratories under FSSAI

4. Spreading Food Safety Awareness – It is the responsibility of FSSAI to spread awareness and inform the citizens about the importance of safe and hygienic food consumption. Any food safety-related threat must be informed to the Government authorities for further action. Also, assist them in framing food standard policies.

5. Maintain Records and Data – FSSAI also has the responsibility to maintain proper records and data of all the registered organisations. **Any violation of rules prescribed by FSSAI can lead to the termination of the license.**

Structure of FSSAI

The structure of the Food Safety and Standards Authority of India comprises:

- Chairman – Appointed by the Central Government
- **22** other members, of which **1/3rd must be women-**

7-Agriculture, Commerce, Consumer Affairs, Food Processing, Health, Legislative Affairs, Small scale Industry.**2-** Food Industries **2-** Consumer organisation. **3-** Food Technologists/ scientists **5-** State/UT zones **2-** Farmer organisations **1-** Retailer organisations

Apart from this, a strong team of scientists and researchers for the testing of food quality. Separate committees and panels are also formed with experts from scientific backgrounds.

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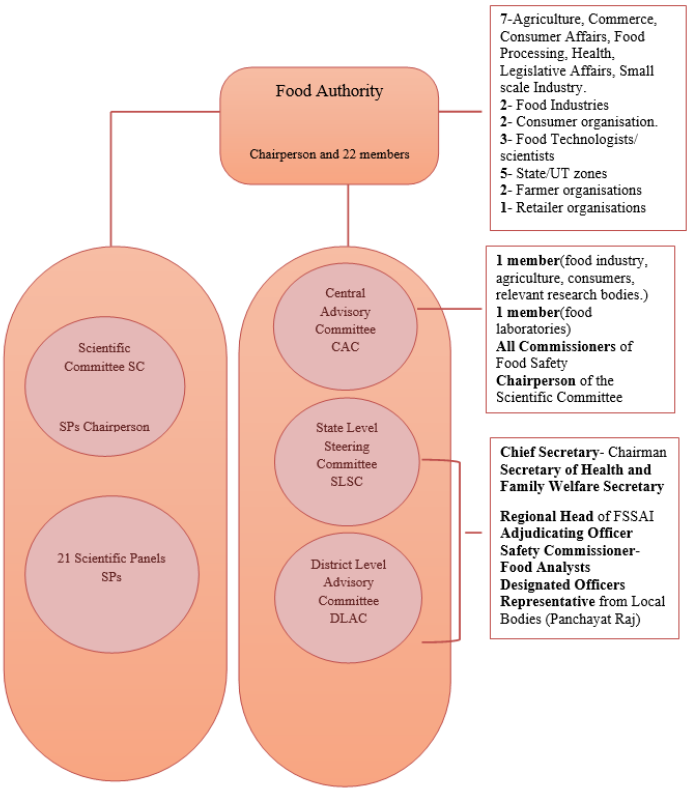
Scientific Panels (SPs)

1. The SPs are constituted for the **purpose of developing standards**, and also to provide scientific opinion/inputs to the Food Authority, as and when sought.
2. The Food Authority can establish as many SPs as it deems necessary.
3. The FSS Act clearly provides the term, number of Members, and eligibility criteria for selection of Members of SPs.
4. Each comprising of 9 members and comprising of **21 SPs on 24.02.2023, which are operational with effect from 01.03.2023:**

SP Nos.	Name of Scientific Panel	SP Nos.	Name of Scientific Panel
SP-01	Food additives, Flavourings, Processing aids & Materials in contact with food	SP-12	Fruits & Vegetables
SP-02	Pesticides Residues	SP-13	Meat & Meat Products, poultry
SP-03	Antibiotic Residues	SP-14	Milk & Milk Products
SP-04	Genetically Modified Organisms and Foods	SP-15	Oils &Fats
SP-05	Functional foods, Nutraceuticals, Dietetic Products and Other similar products	SP-16	Sweets, Confectionery, Sweeteners Sugar &Honey
SP-06	Biological Hazards	SP-17	Water & Beverages
SP-07	Contaminants in the Food Chain	SP-18	Nutrition and Fortification
SP-08	Labelling and Claims/Advertisements	SP-19	Spices and Culinary Herbs
SP-09	Method of Sampling and Analysis	SP-20	Packaging
SP-10	Fish and Fisheries Products	SP-21	Alcoholic Beverages
SP-11	Cereals, Pulses & Legume and their products (including Bakery)		



1. FSSAI Ensures more than 2 Billion meals Billion meals Billion meals per day per day in the country is safe and wholesome.
2. Street food vendors provide cheap and enjoyable food to millions of consumers. However, it is difficult to ensure the safety of street food, since there are many contributing factors associated with it.
3. Register/Issue Licenses to nearly 35 million FBOs including the small, micro and even temporary vendors in streets.
4. Enforce safety regulations uniformly across the wide spectrum of registered food vendors throughout the country.
5. Inadequate infrastructure - 72 public labs and 3NFLs is not adequate to handle the envisaged increase in number of food samples and the newer types of foods for testing. *(Source: Export import data bank-Ministry of commerce)*
   Thus, creatingawarenessand assuring food safety among the entire population is a herculean task.

Initiatives taken by FSSAI

1. **EAT RIGHT INDIA –** The aim is not just to provide food to one and all, but to provide quality food to everyone. With this initiative, **FSS AIintends to make good quality food accessible to every citizen of the country.**
2. **CLEAN STREET FOOD –** This involves training the street food vendors and making them aware of the violations as per the FSS Act 2006. This will also help in the **social and economic upliftment of street food vendors.**
3. **SAVE FOOD, SHARE FOOD, SHARE JOY –** Encouraging people **to avoid food wastage and promote food donation.**
4. **THE SAFE AND NUTRITIOUS FOOD (SNF)** initiative has been launched to bring about **social and behavioural change** among citizens around food safety, hygiene and healthy diets in all spheres of life- **at 'Home', 'School', 'Workplace' or while 'Eating Out'.**
5. **PLACES OF WORSHIP (PoW)** are a very important part of Indian society and food served in these places is regarded as pure and sacred. BHOG (Blissful Hygienic Offering to God) is initiative to encourage PoW.

Conclusion

Food safety plays a vital role in creating a healthy society and driving economic development. Governments must establish and enforce regulations to ensure safe food for their citizens. In India, previous food safety laws were scattered across different ministries, causing confusion and inefficiencies. To streamline regulations, these laws were integrated into a single comprehensive act. Since 2011, FSSAI, operating under the Ministry of Health and Family Welfare, has actively worked to enhance food safety awareness and implementation across the country. The government's initiatives influence various sectors, but their impact is limited due to insufficient public awareness. To ensure their success, it is crucial to educate people from all backgrounds, including students, homemakers, food industry professionals, policymakers, and researchers.

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INSECTS THAT LEARN: UNRAVELING THE SECRETS OF ADAPTIVE BEHAVIOUR

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Abstract
Insects exhibit a remarkable ability to learn from experience, enabling them to adapt to changing environments and improve their survival strategies. Learned behaviours, unlike innate responses, are acquired through interactions with the surroundings and can be modified over time. This article explores various forms of learned behaviour in insects, including habituation, classical conditioning, instrumental learning, latent learning, and imprinting. Examples such as the habituation of abdominal contractions in *Tenebrio molitor*, classical conditioning in honeybees and cockroaches, and imprinting in fruit flies and butterflies illustrate how insects develop adaptive responses. Understanding learned behaviours in insects is crucial for advancements in ecological studies, pest management, and conservation efforts.

Keywords: Behaviour, conditioning, insect adaptation, learning, and nesting.

Introduction

Behaviour is any action an organism performs in response to a stimulus, and in insects, it plays a fundamental role in survival and ecological interactions. Insect behaviour includes a wide range of activities such as foraging, mating, migration, and communication (Hoy, 2019). These behaviours can be broadly classified into innate and learned behaviours. While innate behaviours are instinctive and genetically encoded, learned behaviours are acquired through experience and are adaptable over time. Learning allows insects to modify their responses based on past experiences, enhancing their ability to navigate complex environments, evade predators, and exploit food resources efficiently. Learned behaviour in insects' manifests in various forms, including habituation, classical conditioning, instrumental learning, latent learning, and imprinting. Each of these learning mechanisms enables insects to refine their responses to stimuli, ultimately contributing to their evolutionary success. This article delves into different types of learned behaviour in insects, highlighting their mechanisms, significance, and ecological implications.

Types of insect behaviour

Innate behaviour: 'Stereotyped' behaviour consists of more or less fixed response or a series of genetically determined responses. Thus, behaviour is stimulus bound and outcome of inherited properties of the nervous system. Innate behaviour is always:

- Heritable — encoded in DNA and passed from generation to generation
- Intrinsic — present in animals raised in isolation from others
- Stereotypic — performed in the same way each time by each individual
- Inflexible — not modified by development or experience
- Consummate — fully developed or expressed at first performance

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Learned behaviour

Learning can be defined as a persistent change in behaviour that occurs as a result of experience. Since a newborn nymph or larva has no prior experience, its first behaviours will be entirely innate. Each individual starts life with a "clean slate": it acquires new skills and knowledge through trial and error, observation of other individuals, or memory of past events. In general, learned behaviours will always be:

- Nonheritable — acquired only through observation or experience
- Extrinsic — absent in animals raised in isolation from others
- Permutable — pattern or sequence may change over time
- Adaptable — capable of modification to suit changing conditions
- Progressive — subject to improvement or refinement through practice

Habituation

Habituation can be defined as a gradual decrease in response, caused by the repeated presentation of a stimulus. It can be differentiated from sensory adaptation (i.e., the organs involved in the detection of the stimulus have a decrease in their sensitivity) or motor fatigue (i.e., if the muscles involved are exhausted due to repeated stimulation (Rankin *et al.*, 1987). In the case of insects, habituation has been demonstrated in ants (Wiel and Weeks, 1996), honeybees (Braun and Bicker, 1992), and fruit flies (Duerr and Quinn, 1982). Additionally, the largest number of investigations on habituation has focused on the order of Diptera e.g., flies and mosquitoes (Duerr and Quinn, 1982; Corfas and Dudai, 1989) and Hymenoptera (e.g., bees, ants, bumblebees, and wasps (Barrass, 1961; Varnon *et al.*, 2021). However, little is known about habituation in Coleoptera, the order of insects that contains the most species compared to any other in the animal kingdom.

Habituation of abdominal contractions in mealworm beetle

The mealworm beetle, *Tenebrio molitor*, undergoes complete metamorphosis, facing predation risks during its pupal stage. To defend itself, the pupa performs circular abdominal contractions. This defensive response gradually diminishes with repeated exposure to the same stimulus, a phenomenon known as habituation. To analyse the habituation of the abdominal contraction response, pupae were exposed to electrical (shock to the head) and tactile (brushing the thorax) stimuli, showing a decline in response to repeated electrical shocks. After the pupae showed habituation to the electrical stimulation, they were alternately exposed to electrical stimulation and tactile stimulation. However, when the stimulus was switched to tactile, the contractions increased, indicating sensitivity to new stimuli (Ichikawa & Kurauchi, 2009).

Habituation of the Proleg Withdrawal Reflex in the larvae of Sphinx hawk moth, *Manduca sexta*

Repeated deflection of 1 or 5 mechanosensory hairs on a proleg at a 60-sec interstimulus interval (ISI) for 20 trials produced a significant decrease in evoked force of proleg withdrawal. Habituated responses recovered after cessation of stimulation or pinch of the body wall (dishabituation) (Wiel and Weeks, 1996).

Habituation and dishabituation of a cleaning reflex in *Drosophila*

The tactile stimulation of thoracic bristles in Drosophila leads to the cleaning reflex behaviour with a patterned set of leg movements. This cleaning reflex undergoes habituation and dishabituation. Repeated monotonous stimulation of the bristles by controlled air puffs leads to decrement, and finally to disappearance, of leg response. Spontaneous recovery of the response takes place in a time-dependent manner. Restoration of response can also be obtained by application of a high-frequency stimulus directed to other bristles (Corfas and Dudai, 1989).

Classical conditioning in insects

Classical Conditioning is learning to associate one stimulus with another, unrelated stimulus. Honey bees, for example, learn to associate floral colors and fragrances with the presence of nectar. They can be "trained" to collect sugar water from colored dishes on a feeding table. If a blue dish with pure water sits next to a yellow dish with sugar water, worker bees will quickly learn to associate "yellow" with "food" (even if the dishes are moved around). When solutions in the two dishes are suddenly swapped (sugar to blue and water to yellow), the bees will ignore blue and continue to forage at yellow until they eventually "learn" (by trial and error) to look for the blue dish. Classical conditioning has been well studied in social *Hymenoptera*, exploring how members of a colony gain foraging benefits from learning to associate various stimuli.

Classical conditioning in cockroaches

Cockroaches underwent differential conditioning trials in which peppermint odour was associated with sucrose solution and vanilla odour was associated with saline solution. Odour preference of cockroaches was tested by allowing them to choose between peppermint and vanilla sources. Cockroaches that had undergone one set of differential conditioning trials exhibited a significantly greater preference for peppermint odour than did untrained cockroaches (Watanabe *et al.*, 2003). Since cockroaches have an innate preference for vanilla odour over peppermint odour (Sakura and Mizunami, 2001), conditioning was designed to associate peppermint odour with reward and vanilla odour with punishment. This memory was retained at least 4 days after conditioning.

Instrumental Learning in insects

Instrumental Learning depends on the animal's ability to remember the outcome of past events and modify future behaviour accordingly. Good consequences (positive feedback) reinforce the behaviour and increase its likelihood of occurrence in the future. Bad consequences (negative feedback) have the opposite effect. Cockroaches learning to run through a simple maze to find food is a simple example of instrumental learning (also known as operant conditioning).

Latent learning in insects

Latent learning is a form of learning that occurs without immediate reinforcement but becomes evident when needed. This concept was first described in vertebrates, particularly in rats navigating mazes (Tolman, 1948). A sand wasp, for example, learns the location of her nest site by taking a short reconnaissance flight each time she leaves the nest. She remembers the pattern of surrounding landmarks to help her find the nest when she returns. Likewise, worker ants can remember a series of landmarks along a trail and follow them (in reverse order) back home to the nest site. Honey bees also show latent learning when they follow the waggle dance of a forager and then use that information to find the reported nectar source.

Latent Learning in ant, *Temnothorax albipennis*

Ant colonies were introduced to a low-quality nest near their current home but were not forced to move. After a week, a second identical nest was introduced, and the original nest was destroyed, forcing emigration. The ants showed a strong preference for the novel nest over the familiar low-quality site, indicating that they had memorized and rejected the previously explored option (Franks *et al.*, 2007).

Imprinting in insects

Imprinting is a special case of programmed learning that occurs early in life and only within a short time-window known as the "critical period". During this brief interval, the animal acquires an

indelible memory of certain salient stimuli in its "home" environment (taste of the host plant, smell of the nest site, etc.). This memory is retained throughout life and recalled later when needed. Fruit fly larvae, for example, will imprint on the taste and smell of their food. If reared on a diet that contains apple extract, adult females will show a strong preference for apples when they eventually search for a place to lay their own eggs. Not just any stimulus will do.

Olfactory Imprinting in Honeybees (*Apis mellifera*)

Honeybee larvae can imprint on floral odours they are exposed to during their development. This early exposure influences their foraging preferences as adults, making them more likely to seek out flowers with similar scents (Dinges *et al.*, 2013).

Sexual Imprinting in Fruit Flies (*Drosophila melanogaster*)

Male Drosophila that are exposed to specific pheromones during early development tend to prefer mates with similar chemical cues in adulthood, affecting reproductive choices and species recognition (Arbuthnott & Crespi, 2009).

Conclusion

Learned behaviour in insects is a vital component of their survival and adaptation strategies. Through processes such as habituation, classical conditioning, instrumental learning, and imprinting, insects can modify their responses to environmental cues, optimizing their interactions with their surroundings. Research on insect learning has far-reaching implications for fields such as agriculture, pest control, and conservation. By understanding how insects acquire and refine their behaviours, scientists can develop more effective strategies for managing pest populations and conserving beneficial species. Continued exploration of insect learning will further uncover the intricate mechanisms that govern these remarkable creatures' adaptability and resilience.

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BUDGET 2025-26: AGRICULTURE AS THE FIRST ENGINE TO REVIVE THE RURAL ECONOMY

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Abstract

Agriculture has been one of the few sectors to demonstrate stable growth, playing a key role in driving India's economic development. However, it has continued to struggle with issues related to farmer welfare and income improvement. Agriculture in the Budget 2025, was in the spotlight, wherein, Finance Minister Nirmala Sitharaman referred agriculture as the "first engine" of development and began her speech by outlining the government's priorities for the sector, and announced nine new missions focused solely on agriculture sector which were designed to spur agricultural growth and productivity, and are seen as an acknowledgement of the sector's inextricable link to the livelihoods of millions. This paper highlights the budget provisions made for agriculture sector in the Budget 2025-26.

Introduction

Agriculture has been one of the few sectors to demonstrate stable growth, playing a key role in driving India's economic development. However, it has continued to struggle with issues related to farmer welfare and income improvement. Undoubtedly, the picture of rural India is changing in recent years due to the efforts of the central government and state governments. But agriculture being a complex sector requires an integrated approach. Along with this, better coordination between the Centre and the states is necessary. The plan, in partnership with states, aims to reach an estimated 10.7 million farmers. Other initiatives include a six-year mission for pulses self-

sufficiency, a five-year mission to boost cotton productivity, creation of a Makhana Board in Bihar to augment production, productivity and processing, and a comprehensive programme to promote horticulture production. On the surface, the initiatives outlined in the budget appear to be a step in the right direction. Yet, while these efforts are commendable, they seem like incremental moves rather than the big, bold, transformative changes needed to revolutionize the agricultural sector in India.

Increasing climate change, floods, droughts and unavailability of cheap agricultural loans have destabilized the younger generation, forcing them to migrate to cities in search of jobs and a better future. In the Budget 2025-26, emphasis has been laid on adopting improved farm technologies in which youth participation is necessary. It can be hoped that this will provide ample opportunities for the youth in rural areas and migration may become an option for them. Animal husbandry, fisheries and dairy are the drivers of development of the agricultural sector. The budget given to these sectors is commendable. This paper aims at highlighting the importance of agriculture as the 1st engine of development of Indian economy as envisaged in the budget 2025-26.

Agriculture budget 2025-26 as the first engine to revive the rural economy

Agriculture takes centre Stage in Budget 2025-26 with New 9 Missions to revive the rural economy as mentioned below:

1. *Prime Minister Dhan-Dhaanya Krishi Yojana* - Developing Agri Districts Programme
2. Mission for *Aatmanirbharta* in Pulses
3. Comprehensive Programme for Vegetables & Fruits
4. Mission for Cotton Productivity
5. National Mission on High Yielding Seeds
6. *Makhana* Board in Bihar
7. Building Rural Prosperity and Resilience
8. Fisheries
9. Urea Plant in Assam

1. **Prime Minister Dhan-Dhaanya Krishi Yojana'** Motivated by the success of the Aspirational Districts Programme, the Government will undertake a *'Prime Minister Dhan-Dhaanya Krishi Yojana'* in partnership with states. Through the convergence of existing schemes and specialized measures, the programme will cover 100 districts with low productivity, moderate crop intensity and below-average credit parameters. It aims to (1) enhance agricultural productivity, (2) adopt crop diversification and sustainable agriculture practices, (3) augment post-harvest storage at the panchayat and block level, (4) improve irrigation facilities, and (5) facilitate availability of long-term and short-term credit. The introduction of PM Dhan Dhaanya Krishi Yojana is expected to have a significant impact to the agricultural landscape in India impacting lives of 17 million farmers. The program is also expected to have a positive impact on Agri inputs sector including seeds, agri warehousing, finance and agri-tech sector with improved access to agriculture technology, creation of market linkages and enhancing farmers income in India. However, it is not immediately clear from the budget document how much funding will be allocated to this scheme.
2. **Mission for Atma Nirbharata in Pulses***:* Ten years ago, Government made concerted efforts and succeeded in achieving near self-sufficiency in pulses. Farmers responded to the need by increasing the cultivated area by 50 per cent and Government arranged for procurement and remunerative prices. Since then, with rising incomes and better affordability, our consumption of pulses has increased significantly. The Government will now launch a six-year mission with an allocation of Rs 1,000 crore for the financial year 2025-26 with focus on *toor* (pigeon pea), *urad* (black gram), and *masoor* (red lentil). Under this scheme, central agencies such as NAFED (National Agricultural Cooperative Marketing Federation) and National Cooperative Consumers' Federation will procure these pulses "as much as offered" over the next four years from farmers who register with these agencies and enter into agreements. These programmes are expected to reduce dependence on import of pulses in addition to leading to crop diversification and improved access to nutrition. This is also expected to create forward market linkages for farmers and FPOs thus facilitating self-sufficiency in pulses and crop diversification.
3. **Comprehensive Programme for Vegetables and Fruits:** With rising income levels, the consumption of vegetables, fruits and *"Shree-Anna"* is increasing significantly. It is encouraging that our people are increasingly becoming aware of their nutritional needs. It is a sign of a society becoming healthier. A comprehensive programme to promote production, efficient supplies, processing, and remunerative prices for farmers will be launched in partnership with states to promote production, efficient supplies, processing, and remunerative prices for farmers. The mission has been allocated Rs 500 crore for 2025-26. Appropriate institutional mechanisms for implementation and participation of farmer producer organizations and cooperatives will be set up. These programmes are expected to reduce dependence on import of pulses in addition to leading to crop diversification and improved access to nutrition. This is also expected to create forward market linkages for farmers and FPOs thus facilitating self-sufficiency in pulses and crop diversification.
4. **Mission for Cotton Productivity***:* For the benefit of lakhs of cotton growers, the Government announced a five-year mission with an allocation of Rs 500 crore for FY 2025-26, focusing on improving the productivity and sustainability of cotton farming while promoting extra-long staple cotton varieties. This 5-year mission will facilitate significant improvements in

productivity and sustainability of cotton farming, and promote extra-long staple cotton varieties. The mission will provide the best of science & technology support to the farmers. Aligned with the country's "Integrated 5F Vision" (Farm to Fibre, Fibre to Factory, Factory to Fashion, Fashion to Foreign) for the textile sector, this will help in increasing incomes of the farmers, and ensure a steady supply of quality cotton for rejuvenating India's traditional textile sector.

5. **National Mission on High-Yielding Seeds:** A National Mission on High Yielding Seeds will be launched, aiming at (1) strengthening the research ecosystem, (2) targeted development and propagation of seeds with high yield, pest resistance and climate resilience, and (3) commercial availability of more than 100 seed varieties released since July 2024. This mission will target the commercial availability, development, and propagation of over 100 high-yielding, pest-resistant, and climate-resilient seed varieties released since July 2024. It has been allocated Rs 100 crore for FY 2025-26.
6. **Makhana board in Bihar:** A makhana board will be established in Bihar to improve the production, processing, value addition and marketing of *makhana* (foxnut). With an allocation of Rs 100 crore for FY 2025-26, the board will provide training and support to makhana farmers, who will be organised into farmer producer organisations (FPO). This will provide a special opportunity for the people of Bihar.
7. **Rural Prosperity and Resilience programme** : This initiative will be launched in partnership with states to address underemployment in agriculture through skilling, investment, and technology. It will focus on rural women, young farmers, rural youth, marginal and small farmers, and landless families. The goal is to generate ample opportunities in rural areas so that migration is an option, but not a necessity. Global and domestic best practices will be incorporated and appropriate technical and financial assistance will be sought from multilateral development banks. In Phase-1, 100 developing agri-districts will be covered.
8. **Fisheries:** India ranks second-largest globally in fish production and aquaculture. Seafood exports are valued at 60 thousand crore. To unlock the untapped potential of the marine sector, the government announced a special plan to introduce an enabling framework for the sustainable harnessing of fisheries from India's exclusive Economic Zone and High Seas with a special focus on the Andaman & Nicobar and Lakshadweep Islands. In this regard, the *Pradhan Mantri Matsya Sampada Yojana* (PMMSY) received a substantial budgetary increase of 64 per cent for 2025-26 compared to the revised estimates for 2024-25.
9. **Urea Plant in Assam:** For self-sufficiency in urea production, Government had reopened three dormant urea plants in the Eastern region. To further augment urea supply, a plant with annual capacity of 12.7 lakh metric tons will be set up at Namrup, Assam to further augment the supply of urea.

Enhanced Credit through Kisan Credit Cards (KCC): The Kisan Credit Cards KCCs facilitate short term loans for 7.7 crore farmers, fishermen, and dairy farmers. The loan limit under the Modified Interest Subvention Scheme will be enhanced from 3 lakh to 5 lakh for loans taken through the KCC.

Food and Fertilizer Sector Subsidies

Gulati and Juneja (2025), distinguished Professor and Fellow, ICRIER, respectively, examined the broader agri-food budget for FY2025-26, and said that govt's approach still heavily revolves around welfare measures and subsidies. They added that food and fertiliser subsidies continue to consume a significant portion of the Budget. The food subsidy for FY26 has been pegged at a budgeted estimate (BE) of Rs 2.03 lakh crore, up by 3% from Rs 1.97 lakh crore in FY25 (RE). As mentioned by them, this focus on consumer subsidies overlooks the fundamental issues that farmers face. While the FM announced reopening of three dormant urea plants in the eastern region and setting up of a new plant with annual capacity of 12.7 lakh tonnes at Namrup, Assam, these are positive steps toward improving self-sufficiency. However, more pressing question remains whether the current fertiliser subsidy policy is effectively promoting the right usage of fertilisers. The fertiliser subsidy, meanwhile, has been reduced from Rs 1.83 lakh crore in FY25 (RE) to Rs 1.56 lakh crore forFY26 (BE). While this reduction may seem like a positive step towards fiscal prudence, the reality of this policy's impact on farmers remains uncertain. Given that India imports around 80% of its natural gas for urea production, fluctuations in global gas prices will continue to heavily influence the cost of fertilisers. Furthermore, the heavy subsidisation of urea - often at the expense of other nutrients like phosphorus (P) and potassium (K) - has led to an unbalanced fertiliser usage pattern across the country. Recommended N, P, K dose (in kg/hectare) in Punjab is118, 51 and 33, but actual is 190, 47.1 and 3.7. Similar distortion is there is other states, impacting soil health and productivity. They further emphasized that the real challenge lies in whether govt can pivot from its current fertiliser subsidy regime to a more efficient and sustainable approach. One potential solution could involve direct cash transfers to farmers. This model would empower farmers to purchase fertilisers at market prices, thereby reducing leakage (currently at 20-30%) and ensuring that the subsidy is used more efficiently. Moreover, govt should encourage the use of technological innovations, such as nano-urea and nano-diammonium phosphate, which can help balance nutrient usage and reduce the environmental damage caused by excess nitrogen use. By allowing fertiliser prices to be

determined by market forces, would not only promote better nutrient use but also help restore the right balance of nitrogen, phosphorus, and potassium in soils. However, such a shift would require strong communication efforts to build trust among farmers and ensure their understanding of the long-term benefits. Overall, while the Budget offers several positive steps for agriculture, it does not seize the opportunity to bring about a comprehensive transformation in the sector. The focus on welfare measures and subsidies, though important, may not be enough to drive lasting change. Now is the time to shift the focus from short-term relief to long-term sustainability.

Government Initiatives for Promotion of Nanofertilizers

Steps being taken by the Government to create greater awareness among farmers and promote the use of nano fertilizers are being mentioned below:

i. Promotion of use of nano urea through various activities like awareness camps, webinars, street plays, field demonstrations, farmer conferences and films in regional languages.
ii. Availability of nano urea and nano DAP by the respective companies at Pradhan Mantri Kisan Samridhi Kendras (PMKSK).
iii. iii. Regular inclusion of nano urea under the monthly supply plan issued by the Department of Fertilizers.
iv. National Campaign on "Efficient and Balanced Use of Fertilizers (including nano-fertilizers)" organized recently by ICAR through Indian Institute of Soil Science, Bhopal.
v. Promotion of use of nano fertilizers during *Vikasit Bharat Sankalp Yatra* (VBSY) launched on November 15, 2023.
vi. Initiatives for ease of use of Nano fertilizers through foliar application through drones and distribution of battery- operated sprayers at retail points have been implemented. For this purpose, Government is actively promoting pilot training and custom hiring spraying services through village level entrepreneurs (Drone Didi). Spraying of nano fertilizers through drones has emerged as a cost-effective method. During the *Vikasit Bharat Sankalp Yatra*, farmers expressed interest in adopting this new spraying technology.
vii. Launching of a mega campaign by Department of Fertilizers in collaboration with Fertilizer Companies for adoption of Nano Urea and Nano DAP in all 15 agro-climatic zones of the country through consultations and field level demonstrations. Further, in collaboration with Fertilizer Companies, Ministry of Fertilizers has launched a campaign for field level demonstration and awareness programmes for Nano Urea Plus in 100 districts of the country.

At present, there is no provision of subsidy on Nano fertilizers by Department of Fertilizers. However, Department of Fertilizers is encouraging its companies to set up Nano fertilizer plants. At present, there is no proposal to bring the production of nano fertilizers under any Production Linked Incentive (PLI) scheme. This information was given by Union Minister of State for Chemicals and Fertilizers, Smt. Anupriya Patel in a written reply to a question in the Lok Sabha on 7 February 2025.

Epilogue

Overall, a budget of Rs 1,71,437 crore has been allocated to agriculture and related sectors. Nine new Missions have been announced. The "*Pradhan Mantri Dhan-Dhanya Krishi Yojana*" aims to increase productivity in 100 districts. This will help in increasing productivity diversifying farming, strengthening irrigation and post-harvest storage capacity. It is being said that 1.7 crore farmers will

benefit from this scheme. All types of farmers will come under its purview. An integrated approach has been talked about on fruits and vegetables. The government is promoting the production of vegetables, fruits and grains along with increasing the income level. For this, the participation of farmer producer organizations and cooperatives will be ensured. Also, schemes will be made in collaboration with the state governments. Self-sufficiency in pulses has also been talked about in the budget. The government has promised to increase the loan limit of Kisan Credit Card (KCC) from Rs 3 lakh to Rs 5 lakh. Increasing the KCC limit will increase the burden on the exchequer by Rs 26,000 crore and will benefit more than 7.7 crore growers, fishermen and dairy farmers. Farmers who are doing commercial farming require more crop loans. Apart from this, the formation of National Makhana Board has also been announced in the budget. Rs 100 crore has been allocated for this. A budget of Rs 10,466.49 crore has been kept for agricultural research, which is not even 0.5 percent of agricultural GDP. A National Mission for Hybrid Seeds has been promised, but only Rs 100 crore has been allocated for this. Research is a long process, the results of which are seen in the long term. The budget also announced the second National Expanded Gene Bank, which will preserve 10 lakh germplasm. It is also important to mention here that in the earlier budget, micro irrigation, soil health card, FPO and sustainable farming were talked about, through which the basic development of the agriculture sector was to be done. Even before this base was ready, we have neglected these areas and moved on to other things. We have taken 300 years to assimilate the Industrial Revolution and 50 years to understand the IT Revolution, but the Intelligence Revolution is going to change our society in just 10-15 years. If this change does not happen in a planned manner, social and economic instability may increase. If we build a 'developed India' without transforming the rural economy, we will create mega-cities that will continue to grapple with uncontrolled population and environmental crisis. Delhi is a prime example of this.

Conclusion

The major challenge and strength of the Indian agriculture sector is small and marginal farmers. Apart from agriculture, more than 80 percent of small farmers are also involved in milk production. The food (Cereals and Pulses) and fodder security of India's population of 140 crores and more than 51.2 crores livestock rests on them. For this reason, paying more attention to farmers and strengthening them, the required support is essential and inevitable so as to develop the agriculture and allied sectors. Overall, this budget will prove to be helpful in farming and employment generation.

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FARMERS FIRST: PRIORITIZING MENTAL HEALTH IN AGRICULTURE

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Farming is frequently portrayed as a tranquil and beautiful way of life, with a strong connection to nature and the countryside. However, the reality for many farmers is significantly more complicated. Farmers are constantly exposed to a variety of stresses, including unexpected weather patterns, market volatility, escalating input costs, and the physical demands of agricultural work. These demands can cause mental health issues such as stress, anxiety, and depression. Furthermore, the seclusion of rural agricultural life, combined with the stigma around mental health, sometimes stops farmers from obtaining the help they require. Despite their critical role in feeding the world, farmers frequently lack access to mental health services tailored to their unique needs, exacerbating the toll on their well-being. Addressing these mental health challenges is essential not only for the individuals involved but also for the long-term sustainability of farming communities. Ensuring access to mental health resources and reducing stigma is key to fostering strong, resilient agricultural communities capable of withstanding both environmental and economic challenges.

Mental Health Challenges in Farming

Farmers encounter unique and constant challenges. Financial uncertainty, driven by market fluctuations and increasing production costs, is a constant concern. Unlike other industries, farmers have limited control over the prices they receive for their products, meaning a single poor season can lead to severe financial strain or even bankruptcy.

Climate change has introduced even more uncertainty into farming, making it harder for farmers to predict and manage their work. Unpredictable weather events like unexpected rains, droughts, and heatwaves not only negatively affect crop production but also contribute to heightened stress levels among farmers. As these extreme weather conditions become more frequent and severe, farmers are left feeling powerless as their crops and livelihoods are destroyed. The emotional toll of witnessing the devastation of years of hard work, often with little to no control over the situation, deepens the mental strain. The increasing unpredictability of weather patterns creates a sense of constant anxiety, as farmers struggle to cope with both the financial impact and the emotional weight of such events. This combination of environmental challenges and emotional stress underscores the growing mental health crisis in farming communities.

Social isolation is another significant factor. Many farmers live in rural areas with limited access to mental health resources. Long hours spent alone in the fields can lead to feelings of loneliness and a sense of disconnection from the broader community.

Moreover, the stigma surrounding mental health in farming communities exacerbates the issue. Farmers are often expected to be tough and self-sufficient, which makes it difficult for them to admit

vulnerability or seek help. This mindset can lead to untreated mental health conditions, increasing the risk of anxiety, depression, and even suicide.

Building Support Systems

Tackling mental health issues in agriculture demands a joint effort from agricultural groups, government bodies, and mental health experts. By working together, these sectors can implement various strategies to foster a supportive atmosphere for farmers. This includes raising awareness about mental health, providing accessible resources, and creating a sense of community among farmers. Additionally, training agricultural professionals to identify mental health concerns can help bridge the gap between farmers and the support they need. Collaboration across these sectors is essential to ensure that farmers receive the necessary care and support to maintain their mental well-being.

Raising Awareness and Education

It is crucial to educate farmers about mental health. Awareness initiatives highlighting the symptoms of stress, anxiety, and depression can help diminish stigma and encourage early intervention. By promoting the understanding that seeking support is a sign of strength, not weakness, these campaigns can foster a more open approach to mental health. This shift in perception allows farmers to feel more comfortable reaching out for help, ultimately creating a path toward healing and better overall well-being. Raising awareness can empower farmers to take proactive steps in managing their mental health.

Peer Support Networks

It's important to create opportunities for farmers to engage with one another. Peer support groups give farmers a platform to discuss their struggles and experiences. Sharing stories with others who understand their challenges can provide both comfort and inspiration. Knowing they are not alone in facing these issues can help farmers feel more supported and encouraged. These connections create a sense of community, fostering mutual understanding and offering valuable emotional support. Peer groups can be a powerful tool in helping farmers cope with their difficulties and maintain their mental health.

Improving Access to Mental Health Services

For farmers, particularly those in rural areas, accessing traditional mental health services can be a significant challenge. Telehealth services and mobile mental health clinics can help address this issue by bringing professional support directly to these communities. These solutions make mental health care more accessible to farmers who may otherwise struggle to reach in-person services. By using technology and mobile units, mental health resources can be delivered efficiently, ensuring farmers receive the necessary care, regardless of their location, and helping to reduce the barriers posed by geographic isolation.

Training Agricultural Advisors

Agricultural extension officers and advisors typically have strong connections with farmers, putting them in a prime position to spot signs of mental distress. By providing training for these professionals to recognize and address mental health issues, they can become key intermediaries in connecting farmers with the support they require. These trained advisors can help identify early symptoms of mental health challenges and guide farmers toward appropriate resources, ensuring timely intervention and care. This approach allows farmers to receive the mental health assistance they need in a familiar and trusted setting.

Policy and Community-Level Interventions

Government policies and community-based programs are vital in tackling mental health issues within farming communities. Financial support such as assistance programs, debt relief, and crop insurance can help ease some of the financial burdens farmers endure. These measures provide a safety net and reduce stress, allowing farmers to focus more on their well-being. Promoting a healthy work-life balance is equally important, as farmers often neglect personal time due to the demands of their work. Reminding them that taking time for family, rest, and hobbies is crucial for mental health can lead to healthier lifestyles. Additionally, organizing community events and workshops can help combat the isolation many farmers experience, fostering stronger social networks and providing emotional support. These collective efforts can significantly improve the mental health of farmers and create a more supportive environment in rural communities.

Media campaigns that normalize seeking mental health support play a key role in reducing stigma. When public figures openly talk about their mental health struggles, it helps create an environment where others feel more comfortable seeking help. Seeing well-known individuals discuss their experiences can inspire farmers to take the necessary steps toward improving their own mental well-being. By encouraging open conversations, these campaigns can help shift societal perceptions, making it more acceptable for farmers to reach out for support and seek the care they need to manage mental health challenges.

Conclusion

Addressing mental health in farming is critical not only for the well-being of farmers but also for the stability of the agricultural sector as a whole. The pressures farmers face financial instability, climate change, isolation, and stigma can have serious mental health consequences if left unaddressed. We must break the silence surrounding mental health to build strong and sustainable farming communities. Raising awareness, fostering peer support, ensuring access to mental health services, and training agricultural professionals are key steps in the right direction. By shifting the culture to one where seeking mental health support is seen as a sign of strength, we can cultivate healthier farming communities. Just as crops need care to thrive, so too do the minds of the people who cultivate them. Investing in the mental health of farmers is an investment in food security and rural well-being. The time to start nurturing this support is now.

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SEED PRIMING : A WAY TOWARDS AGRICULTURAL SUSTAINABILITY

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Abstract
Agriculture relies heavily on various inputs to maximize crop success, with seeds being one of the most crucial thing. However, the use of chemical fertilizers and pesticides poses significant environmental and health risks. To move towards more sustainable agriculture, methods like seed priming have gained popularity. Seed priming involves soaking seeds before planting to enhance germination and improve seedling emergence, even under harsh conditions. Techniques such as hydropriming, osmopriming, halo-priming, thermopriming, and bio-priming optimize seed growth and increase yield potential, offering eco-friendly alternatives to traditional farming practices.

Keywords : Seed Priming, Hydropriming, Osmopriming, Biopriming, Matrixpriming

Introduction

In agriculture to maximize crop's success, farmers aid their harvest with resources that can help in improving their upcoming yield. These resources are known as agricultural inputs which can either be consumable (fertilizers, insecticides, seeds) or capital agricultural inputs (tractor). Amongst all consumable inputs, seeds are a very crucial input in agriculture as they are the originator for almost all the world food crops which are circulated internationally at a very large scale. However, this seed distribution that happens during this circulation introduces various plant pathogens into fresh areas and in spite of numerous advantages the chemical fertilizers and pesticides that are applied in the agricultural process are non-friendly to the environment, which not only affects the health of soil but also plant, animal and humans and puts an unjust economic burden on the farmers. So, we should move towards more sustainable agriculture that could provide some value added solutions to maximize the natural potential of the seeds in the field. Seed priming is one such method prevalent in agriculture which is nothing but a form of seed planting preparation wherein the seeds are soaked before planting. This process hastens the germination process and improves the rate of seedling emergence even under extreme climatic conditions and problematic soils. Priming not only optimizes the harvesting efficiency but can also increase yield potential.

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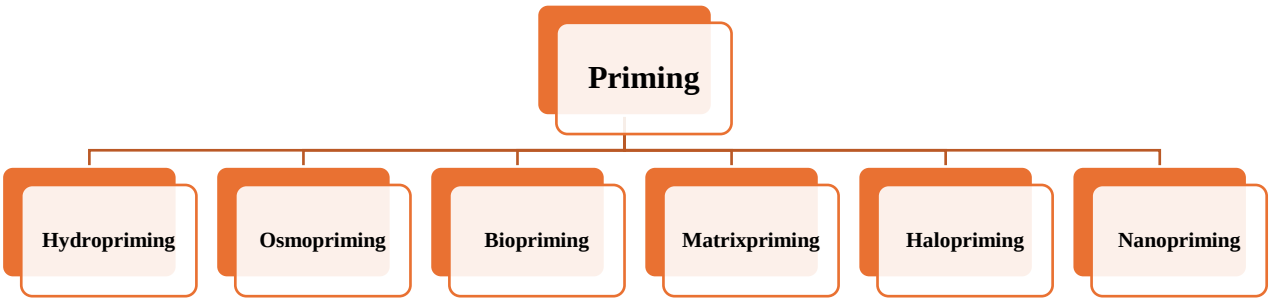


Fig. 1 Seed priming: its importance and types

1. Hydropriming

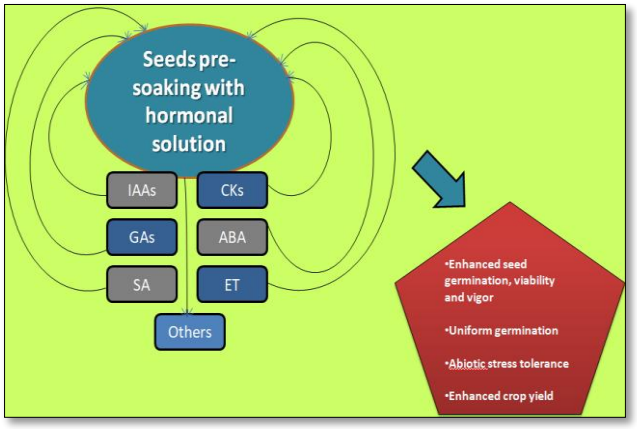
It is one of the most common presoaking seed priming techniques in which the seeds imbibe water and then are dried to their original weight. The whole process of germination can be summed up into three phases:

I) Rapid water imbibition by seed (Phase I)
II) Reactivation of metabolism (Phase II)
III) Radicle protrusion (Phase III)

During radicle protrusion, grain imbibition with water takes place for a limited period of time (7–14 hours) which will initiate the seed metabolism without imposing a significant stress level on the grains and hence complete the first stage of germination without promoting any radicle appearance. In case there is any radicle appearance during the soaking period, the newly developed radicle will die during the seed drying process in the hydro-priming treatment. Hydro-priming led to an increase in the germination rate and seedling vigor index to improve plant growth under stress also.

2. Osmopriming

In osmopriming seeds are soaked in low-water-potential osmotic solutions to undergo the first stage of germination with no sign of radicle protrusion (phase III). The sowing is usually done in the aerated osmotic solutions containing potassium nitrate, potassium phosphate, potassium chloride salts or polyethylene glycol (PEG). These solutions vary in their water potentials and time durations to initiate the membrane repairing systems and metabolic preparation for germination via controlling the water absorption rate of seeds. Among all PEG is widely popular osmo-priming agent that can alleviate the negative impacts of abiotic stresses. It is usually a controlled treatment bringing 10 to 20% of full hydration allowing (phase II) physiological and biochemical events of germination to proceed by inducing abiotic stress conditions.



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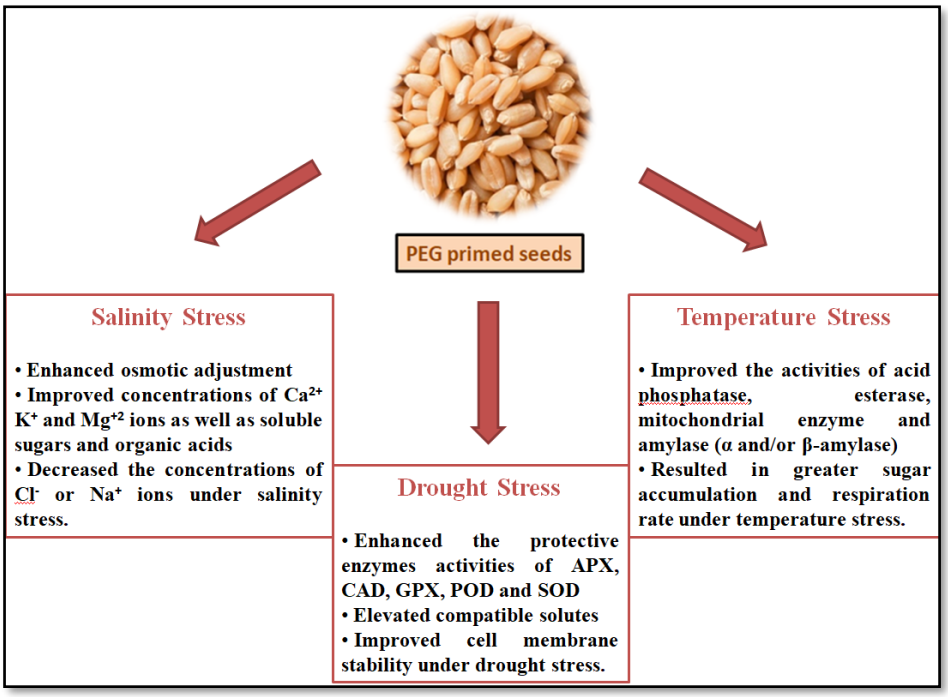

Fig 2: Role of PEG as an osmopriming agent

3. Halopriming

In halopriming, the seeds are immersed in specific aerated aqueous solution of different inorganic salts like $CaCl_2$, $CaSO_4$, NaCl, KNO_3, KH_2PO_4, KCl, etc. which facilitate the process of seed germination and subsequent seedling emergence. The seeds are treated in salt concentrations of tolerable limits prior to germination; alone or in combination, followed by re-drying to their actual weight before sowing into seedbeds.

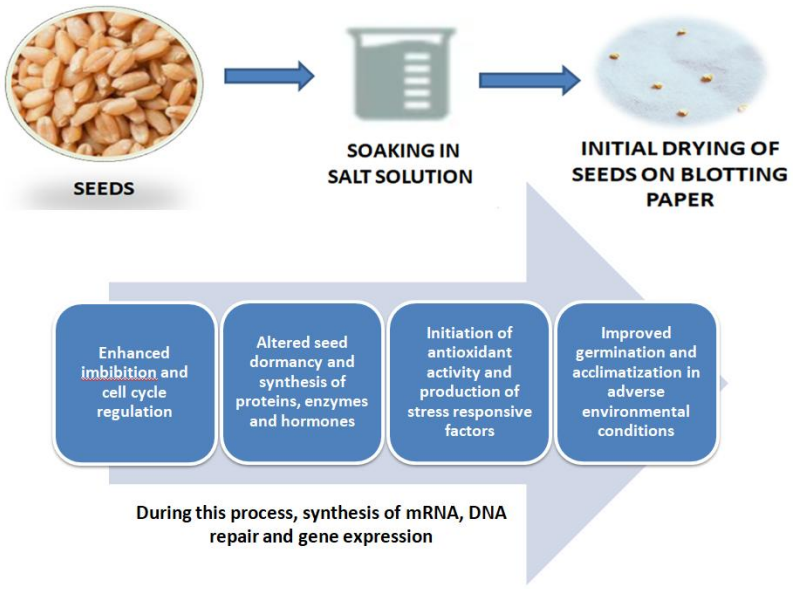

Fig 3: Activation of stress responsive cellular machinery under abiotic stress using halopriming

4. Matrixpriming

Matrix-priming often abbreviated as SMP is solid matrix priming of seeds in which the moistened seeds to be treated are mixed with a predetermined amount of solid organic carrier. The moisture

content of the mixture is brought to a level just below that required for seed sprouting in a vessel that reduces evaporation losses. In this technique the solid phase media provides a structure to hold water and allow gaseous exchange. This technique not only induces systemic resistance to disease and enhances emergence and speed of germination but also allows effective colonization of seed surface before planting given the right pH and matrix material.

5. Nanopriming

It is a form of seed planting preparation in which the seeds are pre-soaked in nano-particle solution ranging from 1 to 100 nm. Comparatively to the bulk particles the ratio of surface area to volume of nano particles increases due to their small size which further enhances their biological reactivity e.g. innovative soil and water remediation solutions, nano-fertilizers, nano-pesticides whose main is to reduce chemical application while enhancing food yield and quality.

6. Bio-priming

Nowadays, bio-priming has gained popularity as an approach of seed treatment which includes inoculation of seed with beneficial microorganisms and seed hydration in order to save the seed from numerous soil borne and seed diseases. Major functions of the beneficial microbes are supply of nutrients to crops, stimulation of plant growth namely producing phytohormones, biocontrol of phyto-pathogens, improving soil structure, bioaccumulation of inorganic compounds and bioremediation of metal contaminated soils. From sustainable agriculture perspective we should aim to reduce the agri-inputs by combining beneficial microorganisms through biopriming.

Conclusion

Priming of seed help the plants to get an earlier root anchorage, improved resistance towards stress and enhanced yield. It helps in rapid and uniform seed germination with higher emergence. It maintains seed vigor for better seedling establishment. It is cost-effective technique which can save time spent on fertilizer application and re-seeding.

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ECOSYSTEM-BASED APPROACHES FOR AQUACULTURE: THE ROLE OF SEAGRASS BEDS

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Abstract
Seagrass is one among the most productive and unexplored marine ecosystems on Earth which occupies less than 0.2% of the ocean floor area and provides various ecological and economic services. In this article, we explore the role of seagrass in carbon sequestration, coastal ecosystem protection, biodiversity support and enhanced water quality. Seagrasses acts as a carbon sink which stores the carbon at a rate of 35 times higher than tropical rainforests and it supports a maximum of 20% of the world's major fisheries. Though it has many advantages, these ecosystems keep on declining with a global loss estimated at a rate of 7% annually due to climate change, pollution and coastal development. So, here we discuss the critical role of the seagrass ecosystem, analyse the current threats and further about the conservation and restoration strategies. Analysing these dynamics is essential for formulating effective policies in protecting these valuable marine habitats.

Keywords: Seagrass, Marine ecosystem, Carbon sequestration, Fisheries

Introduction

Seagrasses are the only flowering plants that are completely submerged in marine environments and have evolved unique characteristics that enable them to provide crucial ecosystem services in coastal waters worldwide. Since their evolution approximately 100 million years ago, these marine angiosperms have developed into 72 species that now form extensive meadows across tropical, temperate and even Arctic waters. The environmental value of seagrass ecosystems extends well beyond their comparatively restricted spatial extent. Occupying only 0.2% of the sea floor, seagrass meadows provide important nursery habitats for commercially valued fish species, store large quantities of atmospheric carbon, enhance water quality and provide erosion protection for coastlines. Yet these essential services are under unprecedented threat from human impacts and climate change, with global loss at alarming rates. This article analyses the diverse roles played by seagrass ecosystems in conserving marine diversity and promoting human well-being and then critiques the problems in conservation and proposes the solutions for the same.

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The Ocean's Unsung Hero: Why Seagrass Matters More Than You Think

Beneath the ocean's surface lies an overlooked ecosystem that's proving to be one of Earth's most valuable natural resources: seagrass meadows. While coral reefs and mangroves often steal the spotlight, these underwater prairies are the real MVPs of marine habitats, providing essential services from fighting climate change to feeding billions. Don't be misled by the name – seagrasses are not grasses at all. They're related more to lilies and orchids and they're the only flowering plants that thrive totally underwater. They evolved from land to sea approximately 100 million years ago and have developed some special features such as underwater pollination and the capacity to photosynthesize in salty environments.

The Ocean's Super-Plant

Consider seagrass the ocean's Swiss Army knife – it does a little bit of everything. To begin with, these underwater grasslands are phenomenal carbon-sequestering machines. Although they cover less than 0.2% of the ocean bottom, they hold approximately 10% of all carbon sequestered in ocean sediments each year. More impressively, they can sequester carbon 35 times more quickly than tropical rainforests. A single acre of seagrass can capture as much carbon as a vehicle emits driving close to 4,000 miles. But wait, there's more. Seagrass meadows are also the nurseries of the ocean, giving shelter and food to thousands of marine animals. One acre can harbor as many as 40,000 fish and 50 million tiny invertebrates. Most commercially valuable fish species have their juvenile stages in these oceanic gardens and therefore, seagrasses are fundamental to world food security. They support a mere 20% of the world's biggest fisheries.

Nature's Water Filter

They're also natural filters of the water. They trap suspended sediment that drifts in the water, making it clearer and can lower levels of pathogenic bacteria in seawater by over 50%. They clean water so efficiently that they've been nicknamed the "lungs of the sea" – one square meter of seagrass produces 10 liters of oxygen daily. Seagrasses are also coastal protectors. Their dense root and leaf networks stabilize the seafloor and dampen wave energy by as much as 40%, shielding shorelines from storms and sea level rise. This natural infrastructure is becoming more and more important as climate change strengthens coastal weather events.

A Hidden Crisis

Even though seagrass beds are critical habitats, they're vanishing at a startling 7% every year, faster than the Amazon rainforest – equivalent to the loss of two football pitches of seagrass every hour. Since the 1930s, around 29% of documented seagrass extent has vanished. These are largely anthropogenic causes. Seagrasses are smothered or denied light by coastal development, water pollution and agricultural runoff. Physical scarification by boat propellers and anchors leaves seagrass beds with scars that take years to heal. Climate change also threatens through increases in water temperature and sea level.

Hope on the Horizon

The good news is that seagrass meadows can recover if protected and restored. Success stories such as the Chesapeake Bay demonstrate what can be achieved with concerted conservation efforts. There, scientists have been able to restore thousands of acres of seagrass by sowing millions of seeds, resulting in water quality and fish population improvements. All of us can contribute to the protection of these important ecosystems. Small actions such as lowering fertilizer application, disposing of waste properly and being cautious while boating in shallow waters can contribute.

Helping local conservation programs and spreading awareness about the significance of seagrass also contribute to ensuring that these underwater grasslands continue to deliver their valuable services.

Looking Forward

As we tackle worldwide issues such as climate change and food security, seagrass meadows present natural solutions for people and the planet. From carbon sequestration to fisheries support, water purification and coastal protection, they are crucial partners in securing a sustainable future. But while most people don't know seagrasses exist, let alone their significance, it is critical to change that through education and awareness. In the same way that public concern over plastic has spurred worldwide action, greater awareness of seagrasses might secure these important ecosystems for generations to come. With over a billion individuals within 100 kilometers of seagrass meadows, their future is inextricably linked to human well-being. By conserving and restoring these sea prairies, we're not only saving vegetation – we're investing in our future. It's time to recognize this unassuming sea meadows' importance and grant them the respect and protection they deserve.

Conclusion

Seagrass meadows support crucial ecosystem services extending far beyond the immediate ecosystem, from their role in supporting global fisheries to coastline protection and carbon sequestration. The progressive loss of seagrass beds globally jeopardizes these essential functions. Conservation problems of seagrass involve complex and multiple scales and thus need integrated, multi-scale solutions that target human direct impacts as well as long-term environmental processes. Effective seagrass and habitat restoration, as seen in areas like Chesapeake Bay, proves that restoration of seagrass is viable through sustained efforts and effective management strategies. Despite this, persisting seagrass meadow loss worldwide verifies that additional measures of protection tactics, public engagement, and governmental action are necessitated.

Future studies must advance our knowledge of seagrass resilience to climate change, optimize restoration methods and place an estimate on the total economic value of seagrass ecosystem services. Increased emphasis must be placed on seagrass conservation mainstreaming in coastal zone management policy and climate change adaptation. Only through concerted effort at local, national and international scales can we conserve these valuable marine ecosystems for the future. The future of seagrass meadows will have a lasting impact on the health of our oceans and the livelihoods of those that rely upon them.

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PARASITOIDS AND THEIR PREY: THE SCIENCE BEHIND PARASITOID HOST SELECTION

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Abstract
Parasitoids are biocontrol agents that are involved in suppressing the pest population in agricultural ecosystems. These biocontrol agents search and find their host for developing its generation. They use a number of host selection processes to locate the suitable host and lay their young ones or eggs. Parasitoids use the visual, tactile, acoustic, allelochemicals, pheromones, and stimuli for locating the suitable host. Factors such as host density, climatic conditions, competition between the parasitoids influence the host selection process. Successful parasitism depends on overcoming host defenses, ensuring the parasitoid's development. Understanding these interactions enhances biological control strategies, reduces the dependence on chemical pesticides and promotes sustainable pest management.

Key words: Biocontrol, host finding, host selection, parasitoid, and pest suppression

Introduction

Parasitoids play a crucial role in biological control by regulating host populations through parasitism. The host selection process is the manner by which hosts are located and further development of the parasitoid-host relationship occurs, overcoming various physical and biological barriers in a habitat. This process consists of four key stages: host habitat finding, host finding, host acceptance, and host suitability. Each stage involves complex behavioural and physiological mechanisms influenced by a variety of cues, including visual, olfactory, tactile, and chemical signals. Parasitoids rely on semio-chemicals such as kairomones, host marking pheromones, and allelochemicals to locate suitable hosts and assess their quality for successful development.

Parasitoids exhibit a high degree of host specificity, which is crucial for their effectiveness as biological control agents. Their ability to differentiate between suitable and unsuitable hosts is influenced by evolutionary adaptations and associative learning mechanisms. Additionally, factors such as host density, environmental conditions, and competition with other parasitoids play significant roles in shaping host selection behaviour. Understanding these intricate interactions enhances our knowledge of parasitoid ecology and their potential applications in sustainable pest management strategies.

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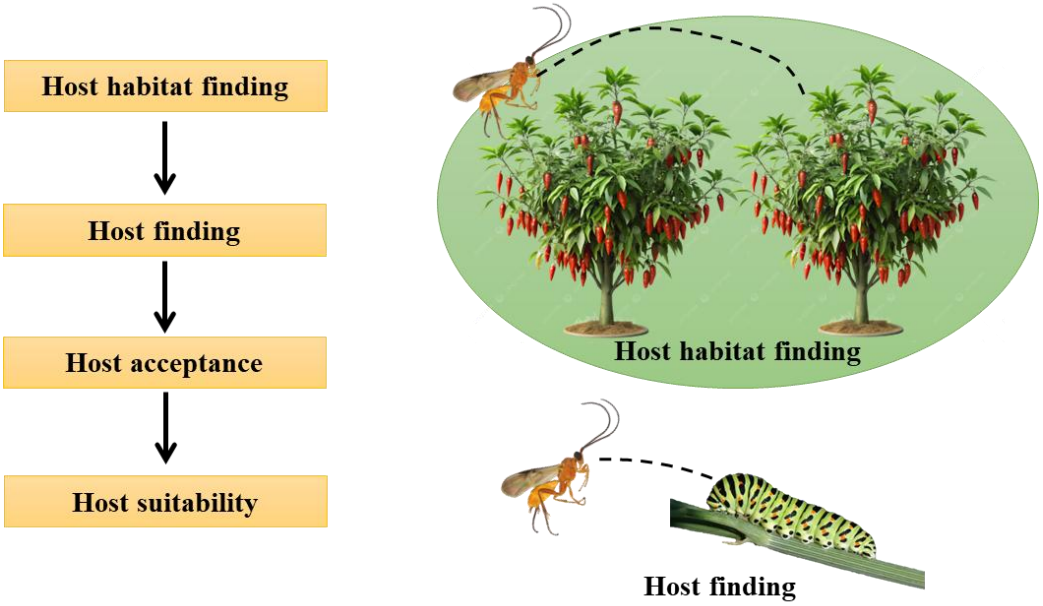
Salt's (1934) steps in HOST SELECTION PROCESS



Host selection process

Host habitat finding

The most diverse group of parasitoid insects are the parasitic wasps, with more than 50,000 described and over a million estimated species (Godfray, 1994). The location of both the host habitat and host is a plastic and flexible behaviour. Host search is a vital component of parasitoid life history (Godfray, 1994). Every parasitoid make use of olfactory and non-olfactory cues to find its host habitat (Geervliet *et al*., 2000; Steidle *et al*., 2003).

Generally, *Cyrtorhinus mundulus* live and breed upon maize and feed upon eggs of corn leaf hopper, *Peregrinus maidis* and also on sugarcane and *Perkinsiella* eggs. In Queensland and Hawaii, maize infested with plenty of leafhoppers was free from *Cyrtorhinus mundulus*, but in sugarcane where only few hoppers are there, *Cyrtorhinus* was plenty. Typically, parasitoids are attracted more strongly by the food plant than by the host insect. First attracted to plant then to host. First activity is seeking the habitat or the environment irrespective of the host. *Aysia manducator* attracted towards the meat with /without the maggots (Laing, 1937).

Host habitat finding by fruitfly parasitoids

The parasitoids of frugivorous Tephritidae, first locates the location of an orchard or fruit tree in which it can find its host. Microhabitat finding is identifying the fruit or patch of fruits; and the parasitoid uses both the volatile semio-chemicals and visual stimuli for locating (Vinson, 1991). Several studies on the behaviour of different species of larval parasitoids have demonstrated that the presence of volatiles associated with the host increases the attractiveness of the infested fruit to the parasitoid. For *Diachasmimorpha krausii* (Fullaway), the fruit is unattractive if uninfested (Ero, 2009).

Cues for host habitat finding

- Visual
- Tactile
- Acoustic

- Allelochemicals
- Pheromones
- Associative learning (conditioning).
- Attract stimuli

Host finding

Location of the host in the habitat is done by random and non-random searching movement. Host finding is mostly done by tactile and olfactory cues. Many sharp turnings are made by the parasitoid on the patch of the host eg. *Nasonia sp.* and finally contacts the host. Egg parasitoids primarily rely on kairomones from the host community to locate oviposition sites since eggs emit few semiochemicals. Studies on *Fopius arisanus* show it responds to volatile kairomones coating tephritid egg masses, with a stronger preference for *Bactrocera zonata* over *Ceratitis* spp. Some parasitoids, like *Utetes canaliculatus* and *Halticoptera rosae*, utilize host marking pheromones (HMP) for host location, though this is less common among egg parasitoids (Noldus *et al*., 1988; Prokopy, 1972).

Several studies suggest that chemical cues emitted by host larva play little role in host detection. Once a female *D. longicaudata* has landed on a fruit, direct chemical cues associated with host larva activity are important for host location. In addition to chemical stimuli directly emanating from the host, mechanical stimuli also play a role in host location by larval parasitoids (Segura *et al*., 2007). The use of aphid honeydew as a host finding kairomone is common amongst the aphid parasitoids. Several studies have now proved that aphidiines use honeydew as a kairomone for host location (Singh and Sinha, 1982; Powell and Zhi-Li, 1983).

Host acceptance

Once the host has been located and contact has been made, the next step for the parasitoid is to accept or reject the host for oviposition. The release of a parasitoid egg into the aphid haemolymph, however, may well be affected by the host's internal physiological conditions as detected by receptors on the ovipositor. Hence, once a female has encountered a potential host, she examines its quality and suitability, by antennation and ovipositor probing, for offspring development. Antennal sensoria are involved in odour perception as well as in the evaluation of contact chemicals on the aphid cuticle by aphid parasitoids. Sensoria on the ovipositor probably aid in the evaluation of host quality during ovipositor probing.

Chemicals associated with hosts, which the female detects after oviposition probing, may influence parasitoid oviposition behaviour. Pennacchio *et al*. (1994) observed that Aphidius microlophii probed non-host aphids with the ovipositor but did not release an egg, indicating that receptors on the parasitoid ovipositor can detect internal cues in the host.

A number of activities are done by the parasitoids before accepting its hosts. These include, Drumming - the process of touching the antenna tip with host, to find motion of the host; Tapping - Tip of the antennae touch with surface of the host, to find locate or ideal site of oviposition (Intersegment membrane); Drilling - To insert ovipositor into the host; Ovipositing - The process of laying eggs into the host; Feeding tube formation – After egg laying, the body fluid of the host oozes out and the parasitoid feeds it by forming feeding tube; Withdrawing - Removal of ovipositor from the host.

Host suitability

Host suitability is concerned with the factors affecting the development of the parasitic stage. The successful development of a parasitoid to the imago depends on several factors including: (a)

evasion of or defense against the host's internal defensive system, (b) competition with other parasitoids, (c) the presence of toxins detrimental to the parasitoid egg or larva, and (d) the host's nutritional inadequacy, which is often a catchall category for otherwise unexplainable phenomena. Many parasitoids evade the host's internal defense mechanism by careful placement of their progeny within certain tissues (ganglion, fat body) or stages (eggs) of the host that afford the parasitoid better protection (Steinhaus, 1963; Salt, 1963). The newly hatched larvae of *Cardiochiles nigriceps* in *Heliothis virescens* (host) actively move about the host hemocoel; using their mandibles, they attack other parasitoid larvae that they may encounter (Vinson, 1972).

Suitability of a host for development may depend on the absence of substances innocuous to the host but toxic to the parasitoid. The emergence of *Apanteles congregatus* from its host, the tobacco horn worm, was reduced when the host fed on tobacco (Gilmore, 1938). However, Thurston & Fox (1972) found that tobacco horn worms fed on tobacco were suitable for the development of the *A. congregatus* larvae but additional nicotine in the diet or applied topically, which had no effect on the host, prevented the parasitoids' emergence from the host (Thurston & Fox, 1972). Pathogenic infection and parasitism of a host may bring about the death of the parasitoid due to early host death (Irabagon & Brooks, 1974).

Conclusion

Parasitoids play a vital role in natural and applied biological control by effectively regulating pest populations through their intricate host selection process. Each stage—host habitat finding, host finding, host acceptance, and host suitability—involves intricate behavioural and physiological mechanisms influenced by environmental cues and evolutionary adaptations. Parasitoids rely on semiochemicals, visual and tactile stimuli, and associative learning to locate and assess hosts. Their ability to overcome host defenses and environmental challenges determines their success in parasitism. By leveraging parasitoid behaviour, researchers and practitioners can enhance biological control programs, reducing reliance on chemical pesticides and promoting sustainable pest management.

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Geocoris BUG: AN EMERGING GENERALIST PREDATOR IN CROPPING ECOSYSTEMS

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Introduction

Natural pest control can be enhanced by utilization of predatory insects that prey on pest population and maintain its population below damaging level, an action known as biological control. *Geocoris* spp.(Hemiptera: Geocoridae) are beneficial natural enemies and are commonly called as Big-eyed bugs or true bugs having piercing and sucking mouth parts with hemimetabolous metamorphosis(egg, nymph and adult stages) with a life cycle duration of 30 days (Ramirez and Patterson, 2011). Big-eyed bugs are referred as generalist omnivores insect which occur world Wide (Tamaki and weeks, 1972). *Geocoris* species are polyphagous and considered to be among the most important predators in cotton, maize, alfalfa, soyabean, straw berry, groundnut and many other crops (Crocker and Comb, 1980). Along with prey, *Geocoris* also been reported to feed on seeds and plant parts (Eubank & Denno, 1999). Immatures (nymphs) and adults *Geocoris* feeds on aphids, whiteflies, thrips, mites, and the eggs and larvae of caterpillars such as tobacco budworm, bollworm and soyabean loopers (Bueno and Van Lenteren,2012).

Morphological characters for identification of *Geocoris* bug

Both adults and nymphs possess oval bodies and broad heads. Their most distinctive characteristic is their large, bulging eyes. They have relatively short antennae that are slightly enlarged at the tip. These bugs walk with a distinctive "waggle" and emits a fowl odor when disturbed. Adults are about 3/16th inch long and silver/gray in appearance. The nymphs look similar to small adults, but lighter and without fully developed wings. Adult's females lays eggs singly on leaves (typically on undersides) and stems of many crops. They are white to tan with a distinctive red spot. Both the adults and nymphs feed by sucking juices from their prey through a needle-like beak. The beak is folded under the insect's body when it is not feeding.(Mead, 2011).

Table 1. Different prey hosts of *Geocoris* spp.

Predator	Prey on	Reference
Geocoris erythrocephalus	Cabbage aphid, *Brevicornye brassicae* (nymphs and adults)	Rajan *et.al.*,(2018)
Geocorisbullatus *Geocoris pallens*	Mustard aphid, *Lipaphis eryisimi* (nymphs and adults)	(Tamaki and Weeks, 1972)
Geocoris superbus	Cotton mealy bug, *Phenacoccus solenopsis* (nymphs and adults)	(Richa and Ballal, 2017)
Geocoris superbus and *Geocoris ochropterus*	Cotton mealybug *Phenococcus sp* (nymphs and adults) and Augoumois grain moth *Sitotroga cerealella* (eggs)	(Varshney and Ballal, 2017)
Geocoris ochropterus	Thrips (nymphs and adults)	(Kumar and Ananthakrishnan, 1985)
Geocoris lubra	*Helicoverpa armigera* (nymphs and adults)	Mansfield *et.al*.,(2007)

Conclusion

Geocoris or Big eyed bug is one of the polyphagous predator it can feed on many insect pests so it is easy to mass culture the *Geocoris* bug by giving different substrates as prey. It is important to remember *Geocoris* also feeds on plant parts like leaves, seeds etc when prey abudance is scarcity. *Geocoris* takes short period of time to complete its total life cycle and also it exhibits many generations in a year. Both nymphs and adults are voracious feeders of lepidopteran as well as sucking pests. so it is important to integrate the mass multiplication of *Geocoris* bug in order to mitigate the pest attack to food crops.

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HERBICIDAL SELECTIVITY: AN OVERVIEW AND TYPES

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Abstract

Selectivity is termed as the ability of a herbicide to control a plant in mixed population without affecting the non-target plants. For selectivity, the herbicide should be less or immobile, very less amount should reach at the site of action, rapid decomposition *i.e.* low persistence in crop plants and high amount should be reached at the site of action in the crop plants. It is complex phenomena achieved by a complex interaction between plants (crops & weeds), herbicide and environment. Selectivity can result from a number of mechanisms, for example, differing uptake, metabolism, or sensitivity of herbicides between plants. For instance, herbicides might affect only particular metabolic pathways or biochemical processes, which are operative in weeds but missing or less vigorous in desirable crops. Furthermore, factors such as the growth stage, environmental conditions, and genetic variation between plant species determine selectivity. Understanding the mechanisms behind herbicide selectivity is critical for developing safer, more efficient herbicides that control weeds without damaging crops, hence promoting sustainable agricultural practices.

Keywords: Crop-weed competition, Metabolic pathways, Site of action, Mode of action

Introduction

Herbicide often have a specific rate of application and are selective. If we apply too little herbicide, no weed control will be achieved and too much of herbicide application may lead to crop injury. But selectivity is more complex than this. It is a dynamic process that involves the interaction of the plant, the herbicides and the environment.

All the species are susceptible to all the herbicides if minimum required quantity of herbicide is reached to the site of action. But the minimum required quantity of applied herbicide is not reached to the site of action of all the species uniformly. With same rate of application herbicide reaching to the site of action varies

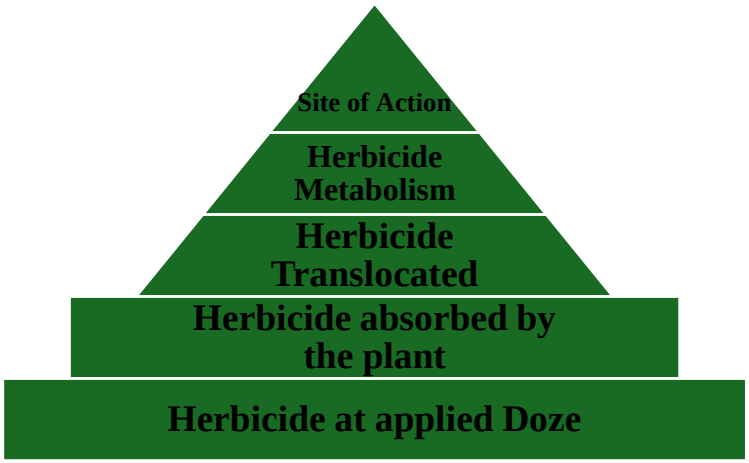

Fig: Pyramid of Herbicide Concentration

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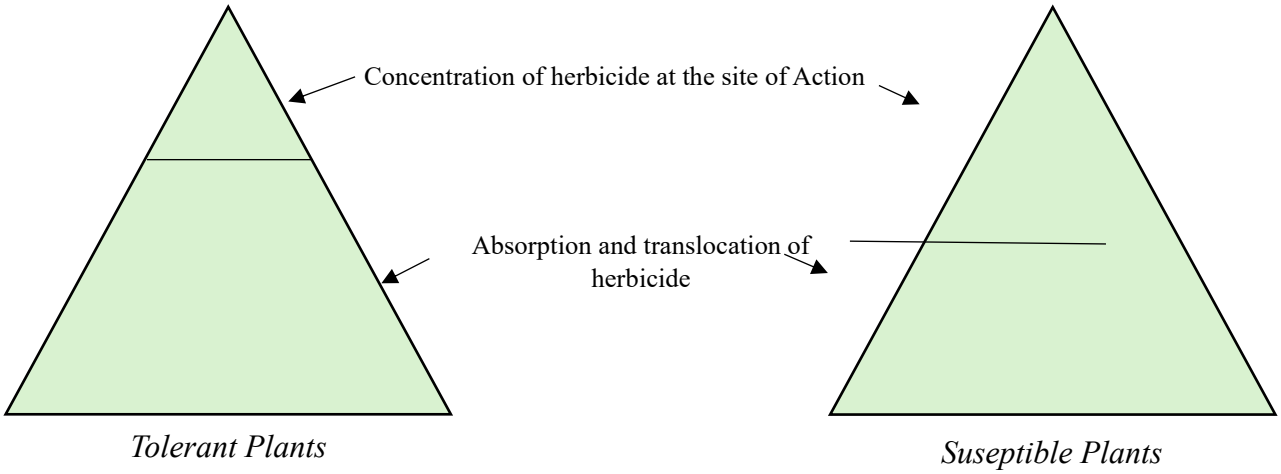
A very small amount/ fraction say one millionth or even less amount of herbicide ultimately reaches to the site of action of a plant and becomes responsible for the herbicidal lethal action. The tolerant and susceptible plants differ highly in the amount of herbicide taken up and translocated by them to the site of action. The susceptible species usually absorb more as well as translocate more amount of herbicide and as a result, the concentration of herbicide at the site of action is higher in the susceptible plants than in the tolerate ones.



Types of Selectivity:

There are mainly four types of selectivity, these are physical, chemical, chronological, biological. At least one of these are must operate when herbicide is applied to the crop. Although more than one kind of selectivity operate under given situation.

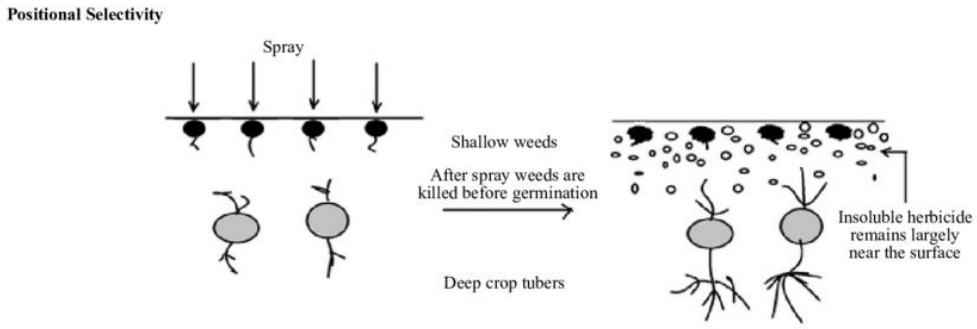
a. Physical Selectivity:

Selectivity to herbicide achieved due to manipulation of various physical factors, *e.g.* depth of sowing, modified application method etc.

i. Depth Protection Selectivity:

All the species are susceptible to all the herbicides if sufficient quantity of herbicide is reached to the site of action. Selective action of herbicide is because the quantity of herbicide reaching to the site of action is different. When crops are protected to come in direct physical contact with the herbicide, the uptake and subsequent movement and reaching to the site of action is prevented.

Weed seeds which are lying in the deeper layer of the normally don't germinate and remain dormant. But the surface-lain seeds getting germinated and cause the weed infestation. When pre emergence herbicide like Pendimethalin is applied in the field the weed seeds which are shallow-placed, getting direct contact with the herbicide and the crop seeds which are placed at the deeper depth of 4-5 cm are not attacked by the herbicide and their germination is not inhibited. **That's why Pendimethalin is considered as an excellent herbicide and can be applied in more than 50 crops**.



ii. Externally-working antidote mediated selectivity:

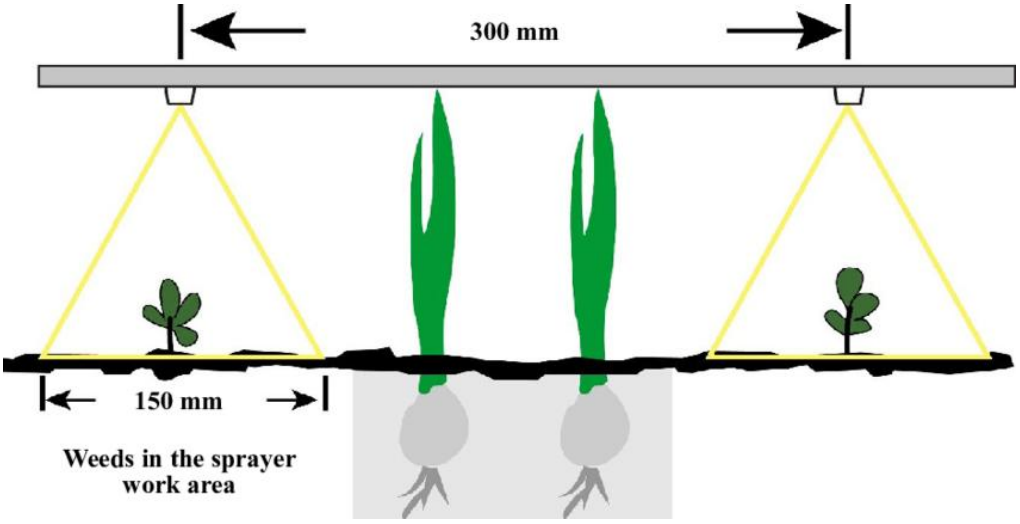
Externally-working antidote pose physical barriers to uptake of herbicide to it's required concentrate. It interfere directly with uptake and indirectly with metabolism of herbicide as well as compete for site of action.

e.g. Activated charcoal placed over seed layer. In paddy against pretilachlor puts a physical barrier and absorb the herbicide.

iii. Application device protection selectivity :

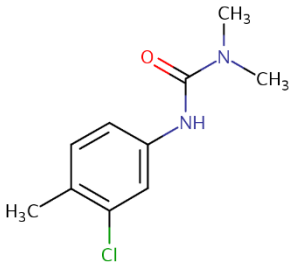
There are some methods and types of application which makes the non-selective herbicides into selective one.

e.g. Spray hood makes 2,4-D selective to Jute. Herbicidal Gloves, rope-wick applicator can be used to make glyphosate selective.

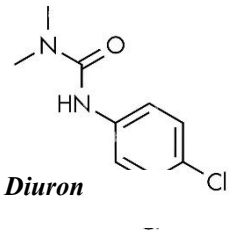


b. Chemical Selectivity:

Activity and selectivity of a herbicide can be changed due to change in the chemical structure and the changes in the functional groups. For example ortho / meta/para position of the '-Cl' in 2, 4-D changes its activity. The 2,4-D ester is highly lipophilic than 2,4-D Na/K and amine and thus high leaf penetration. The 2,4-D ester is highly volatile that's why it is not used in dry areas due to the risk of phototoxicity in the nearby crop fields. Chlortoluron has "-CH3" group, while diuron has "-Cl" group on the 4th carbon position of the benzene ring. But due to this difference diuron is selective to cotton and chlortoluron is selective in wheat



Chemical Structure of Chlortoluron and Diuron



Diuron

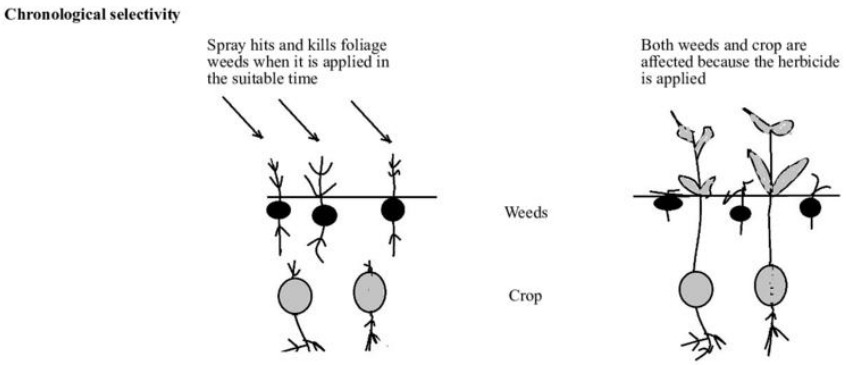
Chlortoluron

c. Chronological Selectivity:

This selectivity is achieved due to manipulation of time of application of a herbicide. This results from the application of the same herbicide as pre-planting, pre-emergence, post-emergence are chronological selectivity.

e.g. Pendimethalin is selective when applied as pre-emergence but not in case of post-emergence. Similarly early post-emergence application of some herbicides at 15-20 DAS may result in greater selectivity than their late post-emergence application at 30-35 DAS.

Paraquat is a non-selective herbicide, but by manipulating the time of application, selectivity can be achieved. Potato takes 15-18 days to emerge. In the meantime most of the weeds germinate and cover the land. Paraquat is recommended to apply when 5-7% sprouting of potato is there to control the weeds selectively.



d. Biological/Biochemical Selectivity:

Selectivity achieved due to metabolism and reverse metabolism of herbicides inside the plants is called biological/biochemical selectivity. It is also known as “True Selectivity”. Differences in morphology and physiology among plants make groups of plants affected or killed by the herbicides, while others unaffected in a mixed flora.

e.g. Propanil is selective to rice but not for the grass weed, Echinochloa colona/ crus-galli. Fenoxaprop-p-ethyl is selective to wheat, but not to grass weeds, Avena fatua and Phalaris minor.

Conclusion

To sum up, the many forms of herbicidal selectivity—such as morphological, physiological, and biochemical selectivity—are essential to efficient weed control. The manner that various plants absorb, move, or metabolize herbicides causes physiological selectivity, which makes certain

species more resistant than others. Herbicides that target particular enzymes or biochemical pathways in some plants while ignoring others are said to exhibit biochemical selectivity. Physical characteristics that can affect the efficacy of herbicides, including leaf structure or root system, are the basis for morphological selectivity. By comprehending and utilizing various forms of selectivity, weeds can be controlled more precisely and specifically, improving crop protection, lowering environmental impact, and increasing agricultural output.

The acknowledgment of various forms of selectivity and their corresponding effects is a more accurate approach than considering selectivity as a binary characteristic. This is essential for maximizing the efficacy of herbicides as an advanced tool.

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THE ROLE OF INDIAN SCIENCE POLICIES IN AGRICULTURAL PROSPERITY, DEVELOPMENT, AND FOOD SECURITY: ADVANCING SUSTAINABLE DEVELOPMENT GOALS

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Abstract
Agriculture has long been the fundamental pillar of India's economy, supporting the livelihoods of a substantial portion of the population and playing a crucial role in ensuring national food security. Recognizing its significance, the Indian government has, in recent decades, introduced a range of science-driven policies aimed at boosting agricultural productivity, fostering sustainable practices, and contributing to the achievement of the United Nations' Sustainable Development Goals (SDGs). This article examines how these strategic policies have been instrumental in advancing agricultural prosperity, promoting rural development and safeguarding food security across India.

Historical Context: The Green Revolution
The Green Revolution of the 1960s marked a turning point in Indian agriculture, fundamentally transforming the nation's food production landscape and setting the stage for rapid economic growth. Spearheaded by visionary agricultural scientist M.S. Swaminathan, this movement introduced a series of scientific advancements, including high-yielding variety (HYV) seeds, improved irrigation techniques, and the strategic use of chemical fertilizers and pesticides. These innovations significantly boosted crop productivity, particularly in staple grains like wheat and rice, leading to a remarkable increase in food grain production.

Before the Green Revolution, India faced frequent food shortages, relying heavily on imports to meet domestic demand. The introduction of HYV seeds, developed through cross-breeding to enhance resistance to diseases and environmental stress, played a pivotal role in overcoming these challenges. These seeds exhibited superior genetic potential, ensuring higher yields even under suboptimal conditions. Additionally, the adoption of advanced irrigation techniques, such as tube wells and canal systems, ensured a steady water supply, reducing dependence on erratic monsoons. This was complemented by the application of chemical fertilizers rich in nitrogen, phosphorus, and potassium, which replenished soil nutrients and further amplified crop productivity.

The success of the Green Revolution was not merely limited to achieving self-sufficiency in food grains; it also catalyzed socio-economic transformations. Increased agricultural productivity enhanced farmers' incomes, reducing rural poverty and stimulating the growth of agro-based industries. Furthermore, the Green Revolution spurred the development of agricultural research institutions, laying the groundwork for continuous scientific innovation. Institutions such as the Indian Council of Agricultural Research (ICAR) played a crucial role in refining HYV seeds and promoting sustainable agricultural practices.

However, the Green Revolution also brought challenges, including environmental degradation due to excessive use of chemical inputs, soil fertility depletion, and water scarcity from intensive irrigation. These issues highlighted the need for a balanced approach to agricultural development, paving the way for subsequent policies emphasizing sustainability and eco-friendly practices. The lessons learned from the Green Revolution continue to shape contemporary agricultural strategies, driving India's pursuit of food security and sustainable development.

By establishing a robust foundation of scientific innovation and productivity enhancement, the Green Revolution not only secured India's food sovereignty but also inspired future agricultural policies focused on sustainability, climate resilience, and inclusive growth. This historical milestone serves as a testament to the transformative power of science and technology in addressing complex agricultural challenges, ensuring prosperity, and achieving long-term food security.

Contemporary Science Policies and Initiatives

Building upon the legacy of the Green Revolution, the Indian government has introduced several policies and programs to address current challenges in agriculture:

1. **National Food Security Act (NFSA), 2013**: Enacted to provide subsidized food grains to approximately two-thirds of India's population, the NFSA aims to ensure food security at the household level. By integrating existing food security programs like the Public Distribution System (PDS), Midday Meal Scheme, and Integrated Child Development Services (ICDS), the Act emphasizes the government's commitment to food security as a legal right.
2. **Climate-Resilient Agriculture**: In response to the growing threats of climate change, Indian scientists have been developing climate-resilient crop varieties. For instance, researchers have introduced rice strains capable of withstanding extreme weather conditions, requiring less water, and offering better yields. Prime Minister Narendra Modi's release of 109 climate-resilient seed varieties underscores the government's proactive approach to adapting agriculture to changing climatic patterns.
3. **Budgetary Allocations for Agricultural Research**: Recognizing the importance of continuous innovation, the Indian government has significantly increased its agricultural budget. In the 2025-2026 fiscal year, the budget saw a 15% rise, amounting to $20 billion. These funds are directed towards developing high-yielding seed varieties, improving storage and supply infrastructure, and boosting the production of pulses, oilseeds, vegetables, and dairy products. Such investments aim to enhance rural incomes, curb food inflation, and reduce dependency on imports.
4. **Long-Term Programs for Specific Crops**: To address the challenges of import dependency and fluctuating domestic production, the government has unveiled long-term programs targeting specific crops. A notable example is the six-year program aimed at increasing pulses production. By directing state agencies to procure pulses at guaranteed prices, this initiative seeks to reduce import dependency and promote self-sufficiency. Similarly, efforts to boost cotton production, particularly the extra-long staple variety, are underway, supported by research and development initiatives.

Alignment with Sustainable Development Goals (SDGs)

India's science policies in agriculture are closely aligned with several SDGs:

- **SDG 1: Zero Hunger**: Initiatives like the NFSA and the development of climate-resilient crops directly contribute to eradicating hunger and ensuring food security.

- **SDG 2: No Poverty**: By increasing agricultural productivity and providing guaranteed prices for certain crops, these policies aim to elevate rural incomes and reduce poverty levels.
- **SDG 3: Responsible Consumption and Production**: Emphasizing sustainable agricultural practices ensures the efficient use of resources, minimizing environmental impact.
- **SDG 4: Climate Action**: Developing and promoting climate-resilient crop varieties and farming practices demonstrate India's commitment to combating climate change and its effects on agriculture.

Challenges and the Way Forward

While significant progress has been made, several challenges persist:

- **Climate Change**: Unpredictable weather patterns and rising temperatures continue to pose threats to agricultural productivity. Ongoing research and the dissemination of climate-resilient crop varieties are crucial to mitigating these effects.
- **Infrastructure and Supply Chain**: Despite increased investments, gaps in storage and supply chain infrastructure lead to post-harvest losses. Strengthening these areas is essential to ensure that increased production translates into food security.
- **Farmer Awareness and Training**: Ensuring that scientific advancements reach the grassroots level requires robust extension services. Training programs and awareness campaigns are vital to equip farmers with the knowledge and tools to adopt new technologies and practices.
- **Policy Implementation**: Effective implementation of policies at the state and local levels is critical. This necessitates coordination among various governmental agencies, adequate funding, and monitoring mechanisms to track progress and address bottlenecks.

Indian science policies have played a pivotal role in reshaping the agricultural landscape, fostering prosperity, development, and ensuring food security. By strategically aligning these policies with the Sustainable Development Goals, India adopts a comprehensive approach to tackling modern agricultural challenges. To sustain this momentum, continued investment in research, infrastructure, and farmer education is essential. Additionally, prioritizing sustainability and climate resilience will be crucial for maintaining the strength of India's agricultural sector and ensuring its capacity to feed an ever-growing population.

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METALS : CURSE OR BOON

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Abstract

Moving from paleolithic period to chalcolithic period, people changed their culture entirely (R.S. Sharma 1999). What's new with the introduction of metals? Metals play crucial role in modern society, impacting almost every aspect of daily life. The sectors of defense, aerospace, agriculture, food industry, medicine, healthcare, electronics, household everything depended on metals only. While metals are highly beneficial, they are also negative impacts on health, the environment, and society. The issues include like mining destruction, air and water pollution, heavy metal toxicity, respiratory issues, cancer risks, costly metal extracting, rusting of metals, high carbon emissions, expensive processing, e-waste crisis, unequal resource distribution, structural failures etc. we need to concern on impacts rather than using in a massive manner. Sustainable mining, better recycling, and alternative metals and more has to launch into global. I summarized the properties of the metals, disadvantages and the changes in our lives after the introduction of metals and methods that we have to follow to eradicate the metal pollution.

Key words : Paleolithic, Chalcolithic, Malleability, Ductility, Corrosion

Introduction

What are the special features of the metals? They replaced everything from beginning with the Harappan civilization of bronze to the development of chalcolithic period (Rs Sharma) and presently, right now we are completely depended on metals. If we look into back of all civilizations, no one are well aware of the metals before they are discovered. Instead of using raw materials like wood, mud, stones, bricks etc all they are replaced by the metals. The outstanding specifications of the metals includes physical and chemical properties in which we can analyze and understand the characteristics of metals. The physical properties include malleability, luster, ductility, high strength, high melting and boiling points, good electrical conductivity, good electrical conductivity and good thermal conductivity and density, hardness etc. Chemical properties include corrosion resistance, reactivity, oxidation resistance and alloy formation. In other aspects how they are affecting our society in a negative manner? Are they really participating in the game of polluting our environment? If we truly seem into the subject, then we will figure out the things. The metal is derived from the Greek word "metallon" means "mine" or " to extract". Aristotle is the primary person who discusses metals in a scientific manner with the help of Robert Boyle.

Cultural changes with the introduction of metals

With the enhancement culture of Indus valley civilization, stone tools are replaced by metal copper tools and later bronze which later they are used for construction (Rs Sharma). Plows, sickles, axes improved agriculture. Metal weapons include daggers, spears, arrowheads gave importance for military superiority. Development of trade brings a new metal revolution in the history. (Rs Sharma) Metal jewelry, statues, and ornaments were crafted. Religious and ritual objects started in the market. The aspect of transportation and infrastructure developed with an exponential ratio. Iron and steel are using for construction bridges, buildings, railways, roads. Copper is used for electrical

writing, plumbing, motors. Aluminum is used in aircraft, automobiles and packing. Electronics sector has developed progressively from 19th century to till now (www.ebom.com). Silicon is a metalloid which is essential for making semiconductors and microchips. Rechargeable batteries of phones, laptops, and electrical vehicles are prepared by lithium. Medicine and Healthcare domain also shows drastic change in the market. Silver is used as antibacterial coatings, while titanium is used in surgical implants and dental implants. Even in agriculture and food industry metals has been using as fertilizers and food processing and storage purposes respectively. Uranium nuclear power plants, electrical grids and solar panels of copper and aluminum has a great market demand. Kitchen utensils and appliances are made up of steel and aluminum. Aircraft, armor, naval ships are also part of metals. For extracting metals someone will get employment opportunities. Metals are indispensable in modern life, driving advancements in every sector.

Drawbacks of metals

As a negativity, extracting metals can cause deforestation, soil erosion, habitat loss. Chemicals like mercury and arsenic will pollute water bodies. Metal refining and smelting releases harmful gases into the air. Sometimes they may cause acid rains which are the combinations of sulfur dioxide and nitrogen dioxide. As we know that metals are Non-Renewable resources, they take millions of years to form. As a health hazards, heavy metal poisoning will be occur in which lead causes brain and kidney damage, mercury causes birth defects and cadmium causes carcinogenic cancers. When we are going with the processes of extracting or mining or welding there is a high chance that metal dusts and fumes can cause skin irritation and lung diseases. Radioactive metals lead to genetic mutations. Working in this area is too much risky. For mining and refining metals, we need very high budget as well as huge manual power. Countries with rich metal deposits may face conflicts, corruption, and exploitation. We have number of examples, Infront of us Where we have seen bridge collapses, building collapses and machine breakdowns due to corrosion activities of iron and steel and this requires constant repairs and replacements. Electronic waste which we are considering now as smartphones, laptops and batteries contain toxic metals, creating a huge pollution problem. Some metals are hard to recycle because they are alloys. Metal industries are releasing large amounts of carbon dioxide, leads to global warming. Even we require high amount of electricity. Some times there will be a chance that metals may accumulate in our body which leads to chronic toxicity over time. Contaminated soils worsen the agriculture, that leads to food poisoning through crops. Food chain will be disturbed by the action of metals. Coal burning releases mercury, arsenic and lead into the atmosphere.

Remedies

There are lot of remedies are there which includes natural, engineered, bioaugmentation, Phyto stabilization, biosorption, phytoextraction, Phyto filtration. Use bio-mining and green extraction methods (bioleaching, hydrometallurgy) to reduce toxic waste. Use chemical or biological methods to remove heavy metals from industrial waste.Prevent direct dumping of waste metal into landfills or water bodies. Treat and neutralize metal waste before releasing it into the environment. Design products with reusable and recyclable metal parts. Set up collection centers for old electronics to extract valuable metals. Recover and reuse metals from e-waste, batteries, and industrial scrap. Install pollution control systems in factories to capture metal particles. Replace toxic metals with safer materials as well as use alternatives like composites, ceramics, or bio-based materials instead of heavy metals. Teach people about safe metal disposal and recycling. Enforce strict rules for metal disposal and recycling. Use nanotechnology by developing eco-friendly methods for metal recovery

and pollution control. By using supercritical carbon-dioxide as a solvent to extract metals which is non-toxic and eco-friendly, leaving no hazardous waste. If we follow all these methods we can reduce environmental pollution, saves energy levels, prevents habitat destruction and land degradation and we can extract metals from waste.

Conclusion

Pollution, which is caused by metals is one of the great existential challenges of the Anthropocene era (Balogh). It endangers the stability of supporting system and threatens the human survival. As a part of nature, it is our responsibility to vanish the pollution which surrounds us. By adopting cleaner mining, better recycling, industrial controls, alternative materials, and strict regulations, we can reduce metal pollution and protect the environment for future generations.

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IMPACT OF MINIMUM SUPPORT PRICE ON AGRICULTURE IN KARNATAKA: CURRENT CHALLENGES AND FUTURE PROSPECTS

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Introduction

The Minimum Support Price (MSP) is a vital agricultural policy tool in India, aimed at safeguarding farmers against market volatility. The government-set price ensures that farmers receive a guaranteed minimum return for their produce, thereby providing them with financial stability in times of market distress. By ensuring a base price for crops, the MSP system helps protect farmers from severe price fluctuations, which can often be exacerbated by unpredictable weather conditions, supply chain disruptions, and other external factors.

Karnataka, an agriculturally rich state in India, plays a vital role in the national agricultural landscape, producing various crops, including food grains, horticulture, cash crops, and commercial crops. The state is a leading producer of crops such as paddy, jowar, groundnut, cotton, sugarcane, and a wide range of fruits and vegetables.

The agricultural sector in Karnataka is not only a source of livelihood but also a critical component of the state's economic growth. It contributes about 13 per cent of Karnataka's Gross Domestic Product (GDP), with more than 55 per cent of the population dependent on agriculture and allied activities for their income. With such a large proportion of the population involved in farming, the MSP system plays a crucial role in ensuring that these farmers do not face financial ruin in the face of fluctuating market prices. The MSP ensures that agricultural activities remain viable, offering farmers a sense of economic security and encouraging continued investment in farming.

Commodities covered under MSP in Karnataka:

The MSP system provides price assurance for a wide range of crops in Karnataka, which is one of the major agricultural states in India. The government sets the MSP for 23 notified crops every year based on factors such as cost of production, market trends, and inflation. The crops notified under MSP are:

Food Grains: Paddy, Ragi (Finger Millet), Wheat, Jowar (Hybrid), Jowar (Maldandi), Maize, Bajra (Pearl Millet) and Barley.

Pulses: Tur (Arhar), Moong, Urad, Gram (Chickpea) and Lentil (Masur).

Oilseeds: Groundnut, Soybean, Sunflower, Rapeseed and Mustard and Safflower.

Commercial Crops: Medium Staple Cotton, Long Staple Cotton, Sugarcane, Tobacco, Copra.

Importance of MSP in Karnataka

The **MSP** is crucial in Karnataka as it ensures farmers receive a fair and guaranteed price for their crops, protecting them from market volatility and price crashes. Additionally, MSP plays a key role in encouraging diversified crop cultivation, as farmers are more likely to invest in crops covered by the MSP. The main objectives of providing MSP are discussed as below:

1. Ensuring farmer income stability

Agricultural income in Karnataka is heavily dependent on monsoon seasons, with over 70 per cent of the state's agriculture reliant on rainfall. Fluctuating crop yields due to unpredictable weather, such as droughts or floods, make farmers vulnerable to income volatility. The MSP system ensures that farmers can secure a minimum price for their crops, reducing the risks of price crashes.

2. Ensuring food security

Karnataka is a leading producer of pulses, oilseeds, and food grains, contributing to India's food security. The state produces about 5.2 million metric tons of food grains annually, which includes paddy, wheat, and maize. MSP serves as a safeguard against price fluctuations, ensuring that the state's food supply remains stable, especially during crop shortages or overproduction cycles.

3. Promoting crop diversification

MSP provides incentives for farmers to diversify their crops and explore high-value, cash crops. The state of Karnataka is known for its horticulture sector, producing mangoes, bananas, coconuts, and coffee. With MSP's assistance, farmers have more confidence in diversifying their agricultural portfolio beyond staple crops like rice and wheat.

4. Protection against market volatility

Agricultural markets in Karnataka are highly susceptible to market volatility. For example, during bumper crops or season excess, market prices often fall below the production cost, leading to significant farmer distress. The MSP system, acting as a floor price, ensures that farmers receive a fair return regardless of these fluctuations.

Key Challenges with MSP in Karnataka's Agriculture

While the MSP system in Karnataka offers essential protections, there are several implementation challenges that reduce its effectiveness in ensuring fair prices for all farmers.

1. Limited crop coverage

Karnataka grows a wide range of crops, but MSP is often limited to select food grains. Crops like sugarcane, coffee, cotton, and horticultural products (e.g., mangoes, bananas) are either partially or entirely excluded from the MSP mechanism, leaving farmers vulnerable to market price swings.

2. Inadequate procurement infrastructure

One of the critical problems with MSP in Karnataka is the lack of procurement centers and insufficient storage facilities. There are only 1,800 procurement centers spread across the state, primarily focused on paddy and wheat, with very few procurement centers dedicated to horticultural crops.

3. Low awareness and participation among farmers

A significant number of farmers in Karnataka are unaware of MSP schemes or face difficulties navigating the procurement process. According to a study by the Karnataka Rajya Raitha Sangha (KRRS), around 60 per cent of farmers in the State did not fully understand the MSP system. Consequently, they often do not participate in MSP schemes and are forced to sell their produce to intermediaries at lower rates.

4. Middlemen and malpractices

Middlemen continue to dominate the agricultural supply chain in Karnataka. Farmers, especially those in rural and remote areas, often sell their produce to middlemen at prices well below the MSP.

Corruption at various stages of procurement has further hindered the successful implementation of MSP. According to the study conducted by The Hindu in 2020 found that up to 40 % of MSP payments in Karnataka were delayed due to inefficiencies in the procurement system, leading to financial stress for farmers.

5. Delayed Payments

Delayed payments are another significant issue in Karnataka. Even if farmers are able to sell their produce at MSP, there are often delays in payment processing, which forces them to borrow money from informal sources at high-interest rates. According to the Economic Survey of Karnataka 2020-21, 30 % of MSP payments were delayed, causing farmers to experience cash flow issues.

Prospects of MSP in Karnataka

Despite the challenges, there are several prospects and opportunities to improve the MSP system in Karnataka. The State can undertake several reforms to enhance the effectiveness and reach of MSP.

1. Expansion of MSP to more crops

One of the most significant prospects for MSP in Karnataka is to expand its coverage beyond food grains to include other critical crops such as coffee, sugarcane, cotton, and horticulture products like mangoes and bananas. Extending MSP to crops with commercial value will ensure that farmers growing these crops also benefit from a stable income.

2. Strengthening procurement infrastructure

Karnataka can invest in improving procurement infrastructure by setting up more procurement centers, particularly in remote agricultural regions. Expanding storage facilities will also help in managing the excess produce during bumper harvests, reducing distress sales.

3. Public-Private Partnerships (PPP)

Karnataka can also encourage Public-Private Partnerships (PPP) to improve the procurement and distribution of MSP-covered crops. The involvement of private sector players in the procurement process will help create more efficient supply chains, reducing the burden on government systems.

4. Technology and digital integration

Introducing technology-driven solutions for MSP procurement can make the system more transparent and efficient. E-procurement systems and mobile applications that provide real-time price tracking and procurement updates could help reduce middlemen exploitation and ensure transparency.

Conclusion

The Minimum Support Price (MSP) is a vital mechanism that protects farmers in Karnataka from the volatility of agricultural markets and ensures food security. While MSP has proven to be a lifeline for many farmers, the system's implementation is plagued by issues such as limited coverage, inadequate infrastructure, middlemen exploitation, and delayed payments. To maximize the benefits of MSP, Karnataka must focus on expanding its scope to more crops, improving procurement infrastructure, leveraging technology, and fostering public-private collaborations. With these improvements, MSP can become a more effective tool to ensure fair prices for farmers, protect their incomes, and contribute to the long-term sustainability of the State’s agricultural sector.

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BOOSTING BIOMASS AND OIL YIELD OF MENTHOL MINT THROUGH IFFCO'S NANOFERTILIZERS AND SPECIALITY FERTILIZERS

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Abstract

India is emerging as the largest producer country in respect of menthol oil. Use of IFFCO innovative inputs like Nano Urea Plus, Nano DAP, bio-fertilizers like NPK liquid consortia, bio stimulant like Sagarika, a sea weed extract, 100% water soluble fertilizers, balanced use of nutrients including secondary and micronutrients along with good agricultural management plays an important role towards boosting biomass and oil yield of menthol mint. This paper aims highlighting the importance of IFFCO Nanofertilizers and other innovative inputs if used in a planned and judicious way could be effective in significantly increasing the oil yield and income of menthol mint growers.

Introduction

In Uttar Pradesh, farmers are benefiting greatly with the cultivation of menthol mint crop in the fields that are vacant after harvesting of *Rabi* crops. Although the history of menthol mint cultivation in India is about 50 years old, but after the development of scientific techniques, menthol mint cultivation in Uttar Pradesh has become very popular in districts like Barabanki, Sitapur, Lucknow, Moradabad, Badaun, Rampur, Bareilly etc. Today India is emerging as the largest producer country in the fields of menthol mint oil production. Menthol mint is cultivated in over 3 lakh hectares of area in India. It is known that India once used to import menthol mint oil and its root products, but today the situation is opposite. Today, India is among the top exporter countries in the supply of menthol mint oil. This journey is of just 20 years, in which a new record has been made with the contribution of scientists and hard work of farmers. About 50,000 tons of menthol mint oil is produced in India. This paper highlights the importance of IFFCO Nanofertilizers and other innovative inputs towards increasing the oil production and income of menthol mint growers.

Improved Varieties

Menthol mint varieties developed by Central Institute of Medicinal and Aromatic Plants (CIMAP) are being mentioned here.

Sim Unnati: This is the best variety of Menthol mint species with crop duration of 100 to 110 days, oil production up to 190 kg per hectare, Menthol mint content 5% and more than 1% aromatic oil content which is 15-20% more than other species of menthol mint .

Sim Koshi: This variety produces 140 litres to 150 kg oil per hectare, 0.8 % aromatic oil content.

Sim Kranti: The most special thing about this variety is that it can be cultivated in both winter and summer seasons. Oil production is 100 kg per hectare in winter and 170-210 kg in summer and menthol content is 80%.

Kushal: Cultivation of this variety is done late in the month of April, plants can tolerate waterlogging as well. Hence, this variety can be planted in fields where waterlogging occurs. Oil production is up to 180-190 kg per hectare, menthol content is 77-80%.

Kalka: This is an early maturing variety. Oil production is up to 150 kg per hectare, menthol content is 80%.

Kosi: This variety has the ability to tolerate diseases like leaf spot, rust and powdery mildew, crop gets ready in 90-100 days. Oil production is up to 150 kg per hectare, menthol content is 75-80%. Himalaya: Pest and disease resistant variety, its leaves are broad and it has the ability to grow very fast, yield up to 150 kg oil per hectare, menthol content 80 %.

Gomti: Strong and dark green leaves with light purple color, this variety gives good yield after first harvest, oil production up to 130 kg per hectare, menthol content 74 %.

Sim Saruru : Solid and wide canopy, oil production 130-140 kg, menthol content 79-80%. Disease and insect resistant, high quality, menthol content 83%. Hairy Bihar Caterpillar resistant, wide canopy, crop duration 110 days, menthol content 75-80%. *Damru* disease resistant, yield of about 240 quintals of herb besides 200 kg oil per hectare and menthol content 78-80 %.

MMS-1: Medium height short duration variety with green leaves and more branches, menthol content 84%.

Preparation of Planting Material

Menthol mint can be planted in the field in two ways. In areas where early crop of menthol mint is to be taken (from January to 15 February) roots are used and in areas where menthol mint is to be cultivated as late crop (after 15 February) the crop is planted by preparing nursery through suckers.

Preparation of Suckers: For planting roots (suckers) of menthol mint in one hectare field, first of all a nursery is prepared in the month of August in a well-prepared area of 200 square meters from where suckers are obtained and planted in the field. Plant seedlings should be taken from a healthy nursery or a nursery certified by the government department. Official plant material can also be obtained from CIMAP. If plants are being selected from the previous year's crop, it must be kept in mind that the plants should not have produced seeds. For this, flowers should not be allowed to form in the plants, this can be done by plucking the flowers. In this way, purity will be maintained in the mother plant material. Before planting in the beds, rotten cow dung manure should be mixed thoroughly at the rate of 10 tons per hectare and nitrogen, phosphorus and potash in the ratio of 50:50:50 kg per hectare.

To obtain suckers from the nursery, the roots are planted in the nursery in the month of August. After planting, irrigation should be done as per requirement and special care should be taken that the nursery should not get filled with water. In this way, suckers are ready in the nursery by December or January. To remove suckers from the nursery, a light digging should be done around the plant and the white coloured suckers should be taken out. The use of cultivator is also convenient for removing suckers. The suckers taken out should be sown in the field as soon as possible. If sowing is not to be done immediately, then they should be kept safe in the field by covering them with soil. The suckers should be planted within a fortnight at the most.

Preparing the Nursery: As a late crop of menthol mint, seedlings are used for sowing in the field. In the fields where cereals, pulses, oilseeds are grown during Rabi and the fields are getting vacant by

the middle of April, menthol mint is taken through seedlings. Like suckers, a nursery of about 200 square meters is required for planting saplings in one hectare of field. Before sowing the pieces of these suckers in the nursery, cow dung manure should be mixed well with the soil in the nursery beds. After this, the cut suckers are spread evenly in the beds. 100-125 kg of cut suckers are sufficient for 200 square meter area. For the rapid growth of suckers, they should be covered with loose soil and a thin layer of cow dung manure for a few days. In this way, after about two weeks, the suckers start germinating and small plants start coming out. Such young shoots having at least 6 leaves are ready for transplantation in the field by the end of March or the first week of April.

IFFCO's Smart Fertilizers for Boosting Biomass and Oil Yield of Menthol Mint

In fact, the economic income of the farmers of the country is mostly linked to farming. In such a situation, every farmer wants to increase his income by getting more yield from farming. IFFCO is making sincere efforts to completely modernize the country's Agriculture sector by using smart fertilizers and adopting improved farm technologies which results significant increase in the yield and farmers income. To achieve the goal of higher yield from applied nutrients, IFFCO is creating greater awareness among farmers about the benefits of Nano Urea Plus, Nano DAP, 100% Water Soluble fertilizers, Secondary and micronutrient fertilizers, biofertilizers, Sagarika (Granular and Liquid) and humic acid inputs, which have significantly helped boosting crop yield and farmers profit.

IFFCO is educating farmers to choose right fertilizers and apply them in right quantity at right time and by right method along with the best management practices to get desired results and also emphasizing for use of these innovative inputs for high yield, high quality and high profit through Farmers Group Meetings, Crop Seminars, Field Demonstrations on farmers' fields, Field Days, Crop Harvest Days etc. Through these efforts, IFFCO, apart from many other crops, has introduced robust nutrient management techniques to enable farmers to boost their biomass yield and income from menthol mint crop. On taking feedback about use of IFFCO's innovative products towards boosting biomass and oil yield of Menthol mint from over 100 farmers of different development blocks of the district Barabanki, it was found that Menthol mint crop has got special benefits from IFFCO's Nano Urea Plus, Nano DAP, Sagarika (Granular and Liquid) Biofertilizer like NPK Consortia (Liquid), Water Soluble Fertilizers, secondary and micronutrients, which are being mentioned below.

Use of Nano DAP (Liquid)

On the basis of research results, recently IFFCO Nano DAP has been included in the Fertilizer Control Order after the recommendation of the Government of India. Tests regarding the efficiency of Nano DAP in comparison to granular DAP have been conducted on the fields of farmers cultivating menthol mint. First of all, the roots of the menthol seedlings should be dipped for 30 minutes in a solution prepared by adding 5 ml of nano DAP in one litre of water, and thereafter the seedling were transplanted in the field and after 25-30 days, 4 ml of nano DAP per litre i.e., two and a half caps of nano DAP bottle in one tank of the sprayer is sprayed on the leaves. Crop performance as influenced by root treatment of seedlings and foliar spray of IFFCO Nano DAP, Nano Urea Plus and other speciality inputs is displayed is shown in **Picture 1.** This leads to good growth of roots and ensuring better establishment of seedlings in the field resulting better growth and development of plants and finally higher biomass yield. With the increase in the yield of biomass, it is natural that the oil yield also increases.

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Picture 1. Menthol mint suckers being treated with IFFCO Nano DAP and foliar spray of Nano DAP in nursery to ensure quick growth of seedlings

Root treatment of seedlings coupled with foliar spray of IFFCO Nano DAP help reducing the dose of basal application of granular DAP to the extent of 50%. A view of root treatment of menthol mint seedlings with IFFCO nano DAP (Liquid) and the growth performance of the seedlings in the nursery is depicted in **Picture 2**.

Picture 2. Root treatment of menthol mint seedlings with IFFCO nano DAP (Liquid) and performance of the seedlings growth thereafter.

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Transplantation in the field

In the fields where *Rabi* crops like rapeseed, potato, chickpea or pea, onion, potato etc. were grown, menthol mint seedlings are transplanted. Plough the field well and level it, and make beds of convenient size. After that, these beds should be filled with water up to the ridges. Generally, menthol mint seedlings should be transplanted from 15th February to mid-April. If transplantation is to be done in the month of March, then the distance between the lines should be 50 to 60 cm and the distance between the plants should be 10 to 15 cm, whereas in April, transplantation a distance of 45x10 cm is kept. Transplantation of menthol mint is done in the same way as transplantation of paddy, but there is no need to fill water later. As far as possible, menthol mint should be planted between March and April. Transplanting after 15th April results in less yield. The technology of bed planting was developed by the Central Institute of Medicinal & Aromatic Plants, Lucknow which proved better than flat planting. A view of the planting of menthol mint in the field by this ridge method is displayed in **Picture 3**.

Picture 3. A view of planting menthol mint in the field after harvesting of Rabi crops.

Use of Nano Urea Plus (Liquid)

As we know that urea is the most popular fertilizer for the fulfilment of nitrogen, but crops are able to use hardly 30-40 % of the nitrogen given by urea. The remaining amount pollutes the environment. The world's largest and wholly owned by Cooperatives, Indian Farmers Fertilizer Cooperative Limited (IFFCO) has invented nano technology-based Nano Urea Plus (liquid) fertilizer which is the first nano fertilizer in the whole world. Menthol mint farmers have experienced that two foliar spraying of nano urea plus leads to very good growth of the crop and when the crop is ready for harvesting, while many leaves fall due to the use of granular urea, the leaves do not fall when nano urea plus is used. Oil comes out from the leaves and when the fall of leaves stops, it is natural that the amount of oil increases. Obviously, the use of nano urea not only saves urea, but it

is also cheaper than urea and the problem of environmental pollution also ends. Two foliar sprays of IFFCO Nano Urea Plus in right quantity and at right time may help reducing the dose of Urea to 50%.

Use of Sagarika: To increase yield and product quality of crops, IFFCO has launched a new product known as Sagarika. It is made from seaweed, which has proved effective in increasing the production of crops. Let us tell you that Sagarika is a biological product, which is obtained from red and brown algae growing in sea water on the south-eastern coast of India. Its use promotes the growth and development of plants. It is available in granular and liquid form. Menthol mint farmers are ensuring increase in the yield and profit of Menthol mint by using granular Sagarika at the time of transplantation at the rate of 10 kg per acre and foliar spray of 1 % concentrated solution after one month alongwith Nano Urea Plus.

Treatment of roots with liquid consortia: This is a natural product. They can be used for partial supply of nitrogen and phosphorus in various crops. It helps in restoring the natural fertility of the soil. It increases the efficiency of chemical nitrogen and phosphorus fertilizers, which stimulates plant growth. It makes the soil biologically active. It provides protection from drought and some soil-borne diseases. It increases the yield of the crop. It is used to treat the roots before planting menthol mint.

Use of water-soluble fertilizers: Progressive farmers also use water soluble fertilizers in menthol mint. Water soluble fertilizers are 100% soluble in water. Their fertilizer efficiency is high. They are used by foliar spraying or drip method. They contain more than one nutrient, due to which all these nutrients reach the plants in balanced quantities simultaneously. Their experience is that this input increases crop growth and oil production. Along with these treatments, menthol mint farmers spray 1% concentrated solution of potassium sulphate which contains 50% potassium and 18% sulphur. Due to the supply of potassium as well as fertilizer, the growth of the lock is also high and oil production also increases. Most of these innovative inputs are depicted in **Picture 4**.

Picture 4. IFFCO's special fertilizers used in Menthol mint (Nano Urea, Nano DAP, Sagarika, Liquid Consortium, Water Soluble 19:19:19, 17:44:0, 0:0:50)

Manure and Fertilizer

This is a crop that requires more manure and water, so water and nutrients should be supplied as per requirement. Generally, it is recommended to apply 150 kg nitrogen, 60 kg phosphorus and 40 kg potash per hectare or 60 kg nitrogen, 25 kg phosphorus and 16 kg potash per acre. Out of these, the full quantity of phosphorus and potash and one-third of nitrogen should be applied before planting of suckers. The remaining quantity of nitrogen should be applied in 2 to 3 splits. While applying nitrogen to the standing crop, special care should be taken that the fertilizer does not fall on the leaves. It is not easy to broadcast urea prills directly during the growth of the plants, so foliar spray of nano urea plus (liquid) and Nano DAP @ 4ml/litre proves to be very effective.

Apart from nitrogen, phosphorus and potash, in case of zinc deficiency, zinc sulphate monohydrate should be used at the rate of 20 kg/hectare at the time of transplantation, otherwise 0.3% zinc sulphate solution should be sprayed on the standing crop. In fields where there is sulphur deficiency, 30-40 kg bentonite sulphur per hectare should be mixed in the soil along with phosphorus and potash at the time of transplantation. With the use of balanced fertilizers, there is a significant increase in crop growth and oil production also increases. Instead of spraying urea directly at the time of plant growth, spraying of Nano urea solution (60 ml i.e. 2.5 caps of Nano Urea Plus (liquid) mixed in a sprayer tank) has been found to be particularly suitable. To prevent the leaves from turning yellow, 1% concentrated solution of iron chelate should be sprayed on the leaves. All the quantities of Bentonite sulphur and zinc sulphate monohydrate should be mixed well in the soil at the time of transplantation along with phosphorus and potash fertilizers. Balanced fertilizer use significantly increases the growth of the crop and also increases the production of oil and the economic benefit of the farmer.

Irrigation: Irrigation in menthol mint depends on the type of soil, temperature and intensity of winds. The first irrigation in menthol mint should be done immediately after sowing/planting. After this, irrigation should be done at an interval of 20-25 days and irrigation is necessary after every harvesting.

Pest Management

a) Weed Control: For weed control mix 3.3 litres of Pendimethalin (IFFCO-MC *Jakiana*) 30 EC in 400 litres of water and get sprayed in one hectare as soon as the shoots appear after sowing/transplanting.

b) Insect Control

Termite: Termites damage the roots, as a result germination is adversely affected. Later, when the infestation occurs, the plants may dry. In case of termite infestation in standing crop, use Chlorpyrifos (IFFCO Uzo) at the rate of 2.5 litres per hectare with irrigation water.

Hairy caterpillar: It lives on the lower surface of the leaves and eats the leaves. Due to which the oil content decreases. For crop protection from this insect spray 500 ml of Dichlor Vas or 750 ml of Fenvalerate per hectare by dissolving it in 600-700 litres of water. The eggs laid in the flock and the caterpillars eating in the flock in the initial stage should be collected and destroyed. The moths are attracted by the light and should be killed.

Leaf Wrapper Insect: Its caterpillars eat the leaves while wrapping them. For its control, spray *Monocrotophos* 36 EC at the rate of 1.0 litre per hectare by dissolving it in 600-700 litres of water.

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Disease Control

Disease Root Rot: In this disease, the roots turn black. Pink spots appear on the roots. This disease can be cured by treating the stolons with 0.1 % Carbendazim (Yamato) before sowing/planting. Apart from this, use disease free stolons. Leaf spot: Dark brown spots appear on the leaves. Due to this the leaves turn yellow and start falling. To treat this disease, mix 2 kg of fungicide called Mancozeb (Satsuma) 75 WP in 600-800 litres of water and spray it at the rate of per hectare.

Harvesting: The crop developed by transplanting root suckers in January-February is harvested twice and the crop developed by planting in the month of March-April is harvested only once. The crop developed by suckers is ready for the first harvest in about 100-120 days i.e. by May. After this harvesting, leaves start sprouting again from the cut plants which can be harvested again after 60-75 days. The crop developed through plantation can be harvested in June or July. When the crop ripens, the leaves start turning yellow from the bottom. The crop should be harvested at this time. Delay in harvesting has an adverse effect on the aromatic oil of the plant. Generally, it has been observed that more quantity of herbage is obtained at the time of first harvesting while the quantity of biomass decreases in the second harvesting. Therefore, in order to obtain maximum desired biomaterial from both the harvests, it is necessary that the crop is neither immature nor overripe. The crop should be harvested at the right time.

Yield: Approximately 30 to 40 tonnes of biomaterial is obtained from two harvests of Menthol mint and as a result of its distillation, 150-200 kg of Menthol mint oil is obtained per hectare. Distillation. To obtain essential oil from the organic material of Menthol mint, freshly cut or semi-dried organic material is distilled. Fresh organic material is uniformly filled in the distillation tank. Thereafter, steam is passed in this tank which extracts the essential oil from the organic material and takes it to the condenser. This condenser is continuously cooled with cold water. In this way, the oil mixed with vapor condenses and collects in another vessel. Since the density of oil and water is different, the oil floats on the water in the vessel. This oil is filtered and separated from the water. A special funnel is used to ensure that there is no water in the filtered oil. Still, to remove the water completely, sterilized sodium sulphate is added to the oil which absorbs the water from the oil. Then sodium sulphate is filtered and separated from the oil. This entire process should be done very carefully so that maximum quantity of oil can be obtained.

Direct heat distillation unit: This type of equipment is suitable for marginal or small farmers. Water is filled in the lower part of the tank. A mesh is placed in its upper part to separate it. Biomaterial is filled in the upper part of the mesh. The tank is heated from below. On heating, the vapor goes from bottom to top and the oil is extracted from the biomaterial, passes through the condenser and collects in the vessel (**Picture 5).**

Figure 5. Direct heat distillation unit for extracting oil from menthol biomass

Storage of Oil: When oil has to be stored for a short time, good quality PVC drums should be used. This type of screw drums are available in the market with capacities ranging from 20 litres to 200 litres. Galvanized iron (GI) drums should be used for long term storage. The oil should be filled in the drum till the top surface so that there is no excess air left in it. The filled drums should be kept in a dark and cool place.

Summary

Use of IFFCO innovative inputs like Nano Urea Plus, Nano DAP, bio-fertilizers like NPK liquid consortia, Bioenhancer like Sagarika prepared from sea grass extract, 100% water soluble fertilizers, balanced use of nutrients including secondary and micronutrients along with good agricultural management plays an important role towards boosting the growth and development of the crop. Their planned use proves effective in increasing the biomass yield and oil production in menthol mint, such is the experience of the farmers of Barabanki district. Treatment of roots of the seedlings of menthol mint with nano DAP and its foliar spray in the standing crop after one month has shown a significant increase in the production of biomass and oil. Two foliar sprays of Nano Urea Plus along with Sagarika (Liquid) further boosts plant growth and oil yield. In conclusion, it can be said that by selecting improved varieties, balanced use of fertilizers, planting of seedlings at appropriate distance and appropriate time, and pest (weed, insect, disease) management and adoption of correct method of oil distillation, there is a significant increase oil production and farmers profit and significant increase in income.

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PROMOTING GLOBAL FOOD SECURITY WITH DOLICHOS BEAN (*Lablab purpureus* (L.) SWEET): HARNESSING GENETIC DIVERSITY, SUSTAINABILITY AND HEALTH BENEFITS FOR A RESILIENT FUTURE

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Abstract
Dolichos bean (*Lablab purpureus* (L.) Sweet), a versatile legume from the Fabaceae family, is cultivated worldwide for its edible pods and seeds, used as vegetables, pulses, and fodder. This drought-tolerant crop, native to Southeast Asia, plays a significant role in sustainable agriculture by fixing nitrogen and improving soil fertility. Despite its nutritional benefits, including protein, essential amino acids, and vitamins, and its medicinal properties, it remains underutilized. The plant's genetic diversity, mainly conserved in regions like India, has been explored for breeding efforts to enhance yield, disease resistance, and growth traits. Recent developments in improved varieties, such as photo-insensitive and early-maturing types, demonstrate its potential for broader use. However, further genetic improvements and increased cultivation in arid regions are needed to realize the crop's full potential for food security, soil health, and human well-being.

Keywords: Dolichos beans; Morphology; Food Security; Benefits; Human Health

Introduction

Dolichos bean (*Lablab purpureus* (L.) Sweet), also known as *Dolichos lablab*, is a flowering plant from the Fabaceae family and the Faboideae subfamily. This self-pollinating crop is broadly classified into two main types: *Lablab purpureus var. typicus*, cultivated for its tender and edible pods, and *Lablab purpureus var. lignosus*, grown for its dry seeds used as pulses. Both types are cross-compatible, producing fertile offspring when hybridized. This legume is known by various scientific names, including *Dolichos benghalensis*, *Dolichos lablab*, *Dolichos purpureus*, *Lablab niger*, *Lablab purpurea*, *Lablab vulgaris*, and *Vigna aristata*. It is also recognized by numerous common names worldwide, such as Australian pea, hyacinth bean, bonavista pea, and Egyptian kidney bean. In India, it has diverse regional names, reflecting its widespread cultivation and significance. Indigenous to Southeast Asia, Dolichos bean has been introduced across tropical and subtropical regions, including Africa and the Americas. It is grown for its dual purposes: as a vegetable (tender pods) and a pulse (dry seeds). Farmers also utilize it for stock feed, often supporting the plants with canes or growing them on flat fields for fodder or pulses. Widely cultivated across Asia, Africa, and the Americas, this crop is especially important in India and Bangladesh. The green pods and seeds are consumed as vegetables, while the mature dry seeds serve as a staple pulse. The bean is a multipurpose legume, valued for its role as a vegetable, pulse, fodder, and green manure. In India, it is cultivated in states such as Tamil Nadu, Andhra Pradesh, Karnataka, Madhya Pradesh, and Maharashtra. In Kerala, photosensitive pole varieties are grown in homesteads, where the tender fruits are harvested and cooked. It is also used in dry bean preparations. Dolichos bean is versatile, grown both as a field

crop and in rainfed systems, often intercropped with cereals and other crops like groundnuts and castor. One of the oldest legume crops, Dolichos bean thrives in dry and semi-arid regions, displaying high drought tolerance and adaptability to diverse growing conditions. Beyond its agricultural benefits, the plant enhances soil fertility by fixing nitrogen and adding organic carbon. However, despite its multifaceted utility, the crop remains underutilized, with limited efforts toward genetic improvement and conservation. From a nutritional perspective, Dolichos bean is a rich source of protein, essential amino acids, vitamins, and minerals. It contains dietary fiber, low carbohydrates, and fats, making it ideal for health-conscious diets. It also offers medicinal properties, including compounds beneficial for managing hypertension, promoting digestion, and potentially fighting cancer.

This crop is crucial for ensuring food and income security, particularly for small-scale farmers in arid and semi-arid regions. Its significance in sustainable agriculture and its nutritional value highlights the importance of prioritizing its cultivation and advancing genetic improvements to fully realize its potential.

Morphological Overview

Lablab purpureus is an herbaceous, climbing legume that can be either a warm-season annual or a short-lived perennial with a strong taproot. The plant has a thick, herbaceous stem that typically grows up to 3 feet in height, while its climbing vines can stretch as long as 25 feet. The leaves are trifoliate, with long stems, and each egg-shaped leaflet measures 3-6 inches (7.5-15 cm) in length, widening in the middle. The upper side of the leaflet is smooth, while the underside has short hairs. The plant produces flowers in clusters on an unbranched inflorescence that emerges from the angle between the leaf and the main stem. These flowers can be white, blue, or purple, depending on the variety. The seedpods are smooth, flat, pointed, and range in length from 2 inches (4-5 cm) to 4 inches (10 cm). The pods contain 2 to 4 seeds, which can vary in color, including white, cream, pale brown, dark brown, red, black, or mottled, depending on the cultivar. Lablab purpureus is also a summer-growing legume, which may occasionally grow as a short-lived perennial. It can reach lengths of 3-6 meters. The plant has a deep taproot system, and its stems are either glabrous or pubescent, trailing or climbing. The leaves are alternate and trifoliolate, with the leaflets typically rhomboid in shape, measuring between 7.5-15 cm in length and 8-14 cm in width. The upper surface is smooth, while the underside has a few short hairs. The flowers, typically white to blue or purple, are arranged in racemes borne on elongated peduncles. Lablab pods are linear and can vary in length from 4-15 cm, with 2 to 8 seeds. The seeds are ovoid and laterally compressed, with a prominent linear hilum.

Lablab purpureus is the sole species within the Lablab genus, which includes three subspecies:

1. *Lablab purpureus subsp. bengalensis*, found in tropical regions of Africa, Asia, and the Americas, characterized by tender fruits up to 15 cm in length and 2.5 cm in width.
2. *Lablab purpureus subsp. purpureus*, typically cultivated in Asia for seeds and fodder, is a semi-erect, bushy perennial often grown as an annual. The fruits are short, up to 10 cm by 4 cm, and the plant has a purple tinge and a strong, unpleasant odor.
3. *Lablab purpureus subsp. uncinatus*, originating from East Africa, features smaller fruits, measuring about 4 cm in length and 1.5 cm in width.

The plant produces flowers during the short-day periods, irrespective of the time of planting. The flowers are generally papilionaceous in structure and are self-pollinating. Flowering occurs between 9 a.m. and 5 p.m., and the anthers dehisce from 5 a.m. to 2 p.m. The stigma becomes receptive on

the day of anthesis. Pods are flat or inflated, typically measuring between 5-20 cm by 1-5 cm, and contain 3 to 6 ovoid seeds of varying sizes and colors, including white, cream, brown, red, black, or mottled. Lablab is adaptable to a wide range of soil types, but it prefers well-drained soil and requires full sunlight. The plant is tolerant of drought due to its deep taproot, which allows it to access water from deep within the soil, and can withstand high temperatures, light frost, and occasional flooding. However, it does not thrive in areas with poor drainage or prolonged waterlogging. Germination is epigeal, typically taking around five days, with seeds remaining viable for 2 to 3 years. Lablab plants have a varied growth period, ranging from 75 to 300 days, with early-maturing cultivars starting to fruit in 60-65 days after sowing. Fruit maturation occurs between 150-210 days after sowing, depending on the cultivar and sowing time. The plant's reproductive biology has been observed to show both self-pollination and cross-pollination, with self-pollinated flowers having a higher fruit set and seed yield. However, cross-pollination also occurs, and the flowers attract various insect visitors such as bees, ants, and butterflies.

Breeding

Genetic Resources and Conservation of Lablab: The tropics and subtropics host significant genetic diversity of lablab, though efforts to catalog germplasm from other regions are limited. In Australia and New Zealand, only fodder varieties are maintained. Asian countries like India and Indonesia, alongside the International Livestock Research Institute (ILRI), have focused on germplasm collection and evaluation. India is working on developing short-duration, disease-resistant, bushy, and day-neutral cultivars. The University of Bangalore has cataloged over 250 lines of indigenous and exotic varieties. Ex situ conservation of lablab germplasm is practiced globally, aiding genetic diversity identification for future breeding.

Genetic Improvement of Dolichos: Breeding of Dolichos primarily aims to increase yield, but research remains limited. Studies on genetic control of pod yield indicate that both additive and dominance effects are important, with dominance being dominant. One or two cycles of biparental mating followed by recurrent selection could reduce dominance effects and enhance selection efficiency. Despite its benefits, Dolichos remains underutilized, and breeding efforts have narrow genetic bases. More efficient strategies are needed, including expanded use of available resources, identification of trait-specific genotypes, and introgression of key genes or Quantitative Trait Loci (QTLs). Germplasm surveys and regular exchange between institutions are essential for broadening genetic diversity.

Breeding Efforts: Institutions like ICAR and State Agricultural Universities, including IIHR, have worked on improving Dolichos for vegetable, grain, and fodder purposes. IIHR has introgressed traits like photo-insensitivity and determinate growth, resulting in bush-type vegetable varieties (e.g., Arka Jay, Arka Vijay) and photo-insensitive pole-type varieties. Pedigree breeding is the primary method used, with molecular markers (SSR, SNPs, DArT) accelerating breeding programs. These advancements have improved the efficiency of Dolichos breeding, supporting sustainable production.

Notable Dolichos Varieties Introduced for Use in Vegetables, Pulses, and Fodder

1. **Arka Adarsh**: Pole-type, photo-insensitive, early-maturing variety with dark green, clustered pods. Ideal for Karnataka. Developed from F7 of (IIHR 178 × Arka Swagath). Yield: 30 t/ha in 120 days.

2. **Arka Krishna**: Similar to Arka Adarsh, pole-type, photo-insensitive, early-maturing variety with dark green, clustered pods. Suitable for Karnataka. Developed from F7 of (IIHR 178 × Arka Swagath). Yield: 30 t/ha in 120 days.
3. **Arka Pradhan**: Pole-type, photo-insensitive, smooth, shiny green pods with undulating surfaces. Suitable for Maharashtra. Developed from F7 of (IC 556824 IPS-2 × Arka Swagath). Yield: 35 t/ha in 120 days.
4. **Arka Visthar**: Pole-type, photo-insensitive variety with long, broad, dark green pods. Suitable for Tamil Nadu and North Eastern states. Developed from F7 of (IIHR 178 × Arka Swagath). Yield: 37 t/ha in 120 days.
5. **Arka Bhavani**: Pole-type, photo-insensitive, with slender, wavy, dark green pods. Ideal for Andhra Pradesh. Developed from F7 of (IIHR 178 × Arka Swagath). Yield: 32 t/ha in 120 days.
6. **Arka Prasidhi**: Pole-type, photo-insensitive, long, flat, slightly curved dark green pods, resistant to rust. Suitable for South India. Developed from F7 of (IC 556824 IPS-2 × Arka Swagath). Yield: 37 t/ha in 120 days.
7. **Arka Swagath**: Pole-type, photo-insensitive, medium-length light green pods. Suitable for Karnataka. Developed through pureline selection from IC 556736. Yield: 26 t/ha in 120 days.
8. **Arka Amogh**: Medium-tall, photo-insensitive plants with wavy, green pods, ready in 55 days. Suitable for Maharashtra. Developed from F7 of (Arka Jay × Arka Vijay) × Konkan Bhushan. Yield: 19-20 t/ha in 75 days.
9. **Arka Sambhram**: Medium-tall, photo-insensitive, flat, light green pods, ready in 55 days. Suitable for Tamil Nadu. Developed from F7 of (Arka Jay × Arka Vijay) × Konkan Bhushan. Yield: 19-20 t/ha in 75 days.
10. **Arka Soumya**: Medium-tall, photo-insensitive, slender, wavy green pods, ready in 55 days. Suitable for Andhra Pradesh. Developed from F7 of (Arka Jay × Arka Vijay) × Konkan Bhushan. Yield: 19 t/ha in 75 days.
11. **Arka Vijay**: Dwarf, bushy, erect, photo-insensitive plants with short, dark green pods and bold seeds. Tolerant to low moisture stress. Developed from F7 of (Hebbal Avare × IIHR 93). Yield: 12 t/ha in 90 days.
12. **Arka Jay**: Dwarf, bushy, erect, photo-insensitive plants with long, light green, slightly curved pods. Excellent cooking qualities, tolerant to low moisture stress. Yield: 12 t/ha in 90 days.
13. **Kashi Khushal (VRSEM-3)**: Semi-pole variety with shiny, dark green pods, 4-5 coffee-colored seeds. Tolerant to high temperatures and DYMV. Rich in protein (635.6 mg/g). Yield: 35-38 t/ha. Recommended for Uttar Pradesh.
14. **Kashi Sheetal (VRSEM-11)**: Semi-pole, low-temperature tolerant, DYMV-resistant variety with 18-20 t/ha yield and rich in protein (590.8 mg/g). Yield: 18.2 t/ha. Recommended for Uttar Pradesh.
15. **Kashi Harittima**: High-yielding Kharif variety with tender, parchment-free pods, resistant to DYMV and pests.
16. **Sarpan Dolichos-3**: Photo-insensitive variety with pods ready in 45-50 days. Yields 130-150 days with two harvests. Characteristic acidic flavor. Yield: 9-12 pods per spike.
17. **Sarpan Dolichos-42**: High-yielding, productive variety with acidic flavor and excellent nutritional value. Yield: 9-12 MT/acre.
18. **Sarpan Dolichos-52**: Similar to Dolichos-42, yielding 9-12 MT/acre with rich nutritional value and acidic flavor. Suitable for year-round production.

Uses of *Lablab purpureus* (Dolichos Bean):

1. **Commercial Crop**: Grown as a pulse crop in Africa, Asia, and the Caribbean for dry seeds, and as a green vegetable (pods, beans, and leaves). It is commonly cultivated in home gardens and mixed cropping systems, with protein isolate from seeds used in food products.
2. **Forage**: Used as excellent forage, hay, and silage, especially when grown with sorghum or millet. Leaves are highly palatable (21-38% crude protein), while seeds contain 20-28% protein.
3. **Cover Crop/Green Manure**: A nitrogen-fixing green manure that enhances soil quality, producing up to 1,750 lbs of leaf matter per acre and improving soil structure.
4. **Wildlife**: Attracts deer and is suitable for food plots, though electric fencing may be needed to protect seedlings.
5. **Edible Uses**: Immature pods and seeds are eaten as vegetables; mature seeds are boiled or sprouted. Roots are also edible, but some varieties contain cyanogenic glycosides and must be properly cooked.
6. **Culinary Applications**: Common in South Asian cuisine, used in curries, stir-fries, and salads. Known as surti papdi, avarekalu, and mochai in India, and sheem in Bangladesh.
7. **Fodder**: Fed to livestock, including cows and goats. Seeds are processed into protein concentrates for animal feed.
8. **Medicinal Uses**: Traditionally used to treat cholera, diarrhea, inflammation, and for its anti-inflammatory, antidiabetic, and aphrodisiac properties.
9. **Soil Improvement**: Improves soil fertility and enhances legume-stover feed quality, particularly in degraded soils.

Plant Protection Measures for Dolichos Beans

1. **Powdery Mildew (*Erysiphe polygoni*)**: This fungal disease is characterized by the appearance of small, white, circular powdery spots on the upper side of the leaves. Over time, the spots spread to cover the entire leaf, stem, petiole, and pods, eventually causing plant death. To manage powdery mildew, spray the affected plants with 0.5% wettable sulphur, or use fungicides such as Benlate or Bavistin at a concentration of 0.15%.
2. **Rust (*Uromyces fabae*)**: Early signs of rust include the appearance of yellow spots on the leaves, petioles, and stems. If left uncontrolled, rust can significantly reduce crop yield. To control this disease, grow resistant varieties and treat the plants with a 3g/l concentration of wettable sulphur or a 1ml/l solution of Dinacap.
3. **Aphids (*Aphis craccivora*)**: Aphids are tiny insects that infest the leaves, stems, and pods of the plant, feeding on the cell sap. This damage can cause the affected parts to dry up and result in poor or no pod formation. To control aphids, apply granular insecticides like Phorate or Aldicarb 10G at a rate of 10-15kg/ha at the time of sowing. Alternatively, spraying the plants with Endosulfan 35EC at a rate of 2ml/l of water has proven effective in controlling aphid infestations.

Health Benefits for Humans

1. **Brain Health**: Copper supports brain functions like dopamine and galactose pathways, promoting mood, focus, and clarity. Deficiency can lead to fatigue, poor concentration, and low metabolism. Copper also aids enzymes like tyrosinase and superoxide dismutase, protecting brain cells from free radicals and potentially slowing aging and reducing neurodegenerative diseases.

2. **Cardiovascular Health**: Vitamin B1 is essential for acetylcholine production, aiding communication between nerves and heart muscles. Adequate intake supports heart function and energy use, helping to maintain healthy ventricular function and manage heart failure.
3. **Cancer Prevention**: Zinc's antioxidant and anti-inflammatory properties help reduce oxidative stress, support healthy cell division, and prevent mutations and tumor growth. It boosts the immune system, reduces infections, and mitigates treatment side effects.
4. **Respiratory Health**: Selenium, manganese, and zinc support lung health, especially in chronic respiratory conditions like COPD. Manganese aids in reducing oxidative stress and inflammation by helping produce superoxide dismutase (SOD), which repairs lung tissue.
5. **Digestive Support**: Fiber aids digestion by preventing constipation with insoluble fiber and supporting digestion with soluble fiber, which forms a gel-like substance. It also promotes healthy gut bacteria.
6. **Insomnia Relief**: Magnesium improves sleep by reducing cortisol and increasing melatonin levels. Studies show magnesium supplementation improves sleep quality and duration, alleviating insomnia symptoms.
7. **Energy Boost**: Iron is essential for oxygen transport and nutrient absorption, supporting energy production. Insufficient iron can lead to fatigue, mood changes, and concentration issues. Adequate intake enhances vitality and muscle coordination.
8. **Gum Health**: Vitamin D, calcium, and phosphorus strengthen bones and gums, forming tooth enamel and supporting jaw bone density. Vitamin D also aids calcium absorption and reduces gum inflammation related to periodontal disease.
9. **Mood Enhancement**: Protein-rich foods provide amino acids that regulate hormones like serotonin and dopamine, promoting mood stability and stress reduction. Balanced protein intake helps control blood sugar, reducing irritability and cravings.
10. **Muscle Cramps Prevention**: Hyacinth beans are rich in potassium, preventing cramps and improving muscle strength. Potassium maintains fluid balance, supports muscle repair, and helps prevent discomfort from cramps and spasms.

Conclusion

Dolichos bean (*Lablab purpureus* (L.) Sweet) is a highly versatile and valuable legume, offering a wide range of benefits from its use as a vegetable, pulse, and fodder to its potential in improving soil fertility. Despite its significant nutritional value and medicinal properties, the crop remains underutilized, with limited efforts in genetic improvement and conservation. By advancing breeding techniques and expanding cultivation, particularly in drought-prone regions, Dolichos can become an even more important resource for food security, sustainable agriculture, and improved health outcomes. The ongoing development of improved varieties highlights its potential for broader use in global agricultural systems.

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ROLE OF INFORMATION COMMUNICATION AND TECHNOLOGY IN WOMEN EMPWERMENT

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Abstract
There has been a lot of interest during the last two decades in employing Information and Communication Technologies [ICTs] for achieving sustainable agriculture and rural development. While many of these initiatives have benefited rural women by way of access to new information and new employment opportunities, women still face a number of constraints in accessing ICTs especially in the agriculture aspect. There is immense potential for ICTs to create new employment opportunities for women and to contribute significant gains in efficiency and effectiveness in women enterprises. The use of ICT has several positive effects on the lives of farmers in different ways, such as crop monitoring, market price tracking and increasing access to financial services. This is how the working approach has been altered by the digital revolution.

Key Words: ICT, women enterprises, digital revolution, rural women

Introduction

In the era of digital transformation, societies' functioning, communication, and access to information have undergone profound changes. Recognizing the pivotal role of digital technologies in fostering gender equality and socioeconomic progress, the Indian government has initiated various projects to empower women and enhance their digital literacy. However, women continue to need help accessing and utilizing digital resources, hindering their full participation in the digital society and economy. Women's empowerment aims to give them more power over the decisions that affect their lives, such as access to resources, participation in decision-making, and control over the distribution of benefits. ICT has the potential to reduce poverty, improve governance, overcome isolation, and give women a voice for those who can access and use them. Held at the 2003 World Summit on the Information Society of Geneva (WSIS), "We are committed to ensuring equal empowerment and full participation of women in every aspect of society and in every decision-making process." In order to achieve this, we should mainstream a gender equality perspective and use ICTs as a tool".

Women Empowerment

- Empowerment is largely defined as a process of change that increases choice (resources) and enhances the capacity to make choices favorable to oneself and to society in general.
- Women's empowerment means women gaining more power and control over their own lives. It can also be seen as an important process in reaching gender equality, which means "rights, responsibilities and opportunities of individuals will not depend on whether they are born male or female.

❖ An empowered woman has control over her own life, both within and outside the home, and she has the ability to influence the direction of social change.

Types of Women Empowerments

1. **Community Empowerment:** Community empowerment refers to the access to new and beneficial information, awareness about the available opportunities, the development of new talents, abilities, confidence, and competence, friendship and support of other women, and involvement in group activities with other women of the community.
2. **Psychological Empowerment:** Psychological empowerment includes an increase in self-worth and confidence, as well as greater inspiration, motivation, passion, and interest to learn new things and to keep fighting for rights and services for rural women.
3. **Organizational Empowerment:** Developing new knowledge and an appreciation of the benefits of technology for rural development via rural cooperatives is a part of organizational empowerment.
4. **Political Empowerment:** Political empowerment refers to greater involvement and representation of women at all levels of the government i.e., Panchayats, Vidhan Sabha (State Assembly), and Parliament.

ICT opportunities for women's empowerment

Enhanced communications and access to information

- ICT offers women a cost-effective way to build and maintain communication with families and friends, as well as with business customers and suppliers. Research illustrates that women leverage phones and the Internet to stay in touch with their families and friends in circumstances where migration or long commutes are a significant factor.

Access to public services

- Since ICT enables the delivery of information and services regardless of time and distance, it can provide essential public services such as education, healthcare and financial services through online or mobile media to a wider range of people including those who used to be excluded or were unable to access such services.

Opportunities for political participation

- ICT and social media are instrumental in encouraging women to be more engaged in politics, and get their voices heard on issues that are at times sidelined by the traditional media outlets.
- A recent research on women's empowerment in South Asia revealed that women in Afghanistan, Bangladesh, India and Pakistan consider ICT as a window to the outside world, and as a platform to get their voices heard.
- ICT helps women create their own space to communicate and share their socio-political thoughts.

Opportunities for socio-economic participation

- The significance of ICT in the socio-economic development is even higher for women, including those who are living below the poverty line.
- The use of ICT can increase efficiency by saving time and money. In both rural and urban areas, ICT has simplified many time-consuming issues (e.g., long distance document transfer and sharing, bill payment, job search, etc.) that once took hours to be done.

Constraints in the Usage of ICT By Women

- Absence of a well-defined national policy to support ICT for the advancement of women.

- Inadequate or limited IT skills, such as installation and maintenance of hardware and software, internet skills (mailing, browsing) etc.
- There isn't much information online in languages outside English.
- Women's time is in high demand. Knowledge overload and the time required to find meaningful and practical information are two obstacles that prevent ICT utilization.
- Social, cultural and religious barriers holding back women's mobility and access to ICT facilities available at public places

Successful ICT Initiatives for Empowering Women

Web-enabled Rural Kiosks (e-Seva centers)

- Web-enabled rural kiosks were created as part of the rural e-Seva centers, which were started as a pilot project in West Godavari District by state government, to offer a wide range of citizen services.
- The programme initially began in each of the district's 46 mandal heads, with the launching of first women's e-Seva centre, in June 2012.
- Initially, at the mandal headquarters, 20 of the 46 larger e-Seva Centers were run by women.
- To launch this project, women from SHGs took out loans, and all of these facilities are currently operating financially.

Savitri Marketing Institution for Ladies Empowerment (SMILE)

- Started as a non-profit organization, located in Pune. It was started as an umbrella for women from marginalized sections to come together and sell their home-made products.
- Utilizing ICT, this organization has raised the literacy rate of disadvantaged women. Internet has also assisted them in marketing their numerous products, such as stuffed animals, candles, bags, and other utilitarian items.
- The Internet enhances the products' visibility and marketability.

Aamagon Soochna Kendra (My Village's Information Centre)

- Odissa government installed 73 Information and Communication Technology (ICT) kiosks in the rural areas of twelve districts, which are operated by women SHGs/Panchayats/NGOs/CBOs/Youth Clubs and Community IT volunteers.
- Women SHG members are being trained at IT Kiosks for a small fee on computer and Internet basics as part of a collaboration with Mission Shakti. Access to IT education has enabled the empowerment of women in these rural and marginalized areas of odissa.

Government Schemes for Women Empowerment

Rastriya Mahila Kosh (RMK):

Provides micro-credit to poor women for income-generating activities

Mahila Shakti Kendra (MSK):

A centrally sponsored scheme to empower rural women through community participation

Mudra loans:

Provide special benefits to women entrepreneur

Sanchar Shakti

- Provides subsidized mobile services to Self Help Groups (SHGs)
- Helps SHGs set up mobile repair centers, modem repair centers, and charging centers
- Aims to increase employment opportunities for rural women

Pradhan Mantri Gramin Digital Saksharta Abhiyan (PMGDISHA)

- Part of the Digital India program, this scheme aims to bridge the digital divide for women and girls in rural areas

Poshan Tracker

- An ICT-enabled platform that monitors Anganwadi services
- Provides real-time data on Anganwadi activities, service deliveries, and beneficiary management

Technology Development and Utilization Programme for Women (TDUPW)

- Helps women develop and use technology to reduce drudgery and build capacity
- Supports projects in areas like food processing, health and hygiene, and nutrition.

Conclusion

ICT has the ability to reach women who, up until now, have not been able to access any other forms of media, enabling them to take part in economic advancement and make educated decisions about issues that directly impact them. Its high time that we make the availability of ICT even to that last woman living in the remotest part of this nation. Empowering women through ICT means to provide economic power to reduce poverty, to develop new opportunity of distance learning and education, bring improvement in health of women, and finally to increase literacy rate among women. ICT emerges as a dynamic force in the effort to empower women, close gaps, and advance society thanks to its wide range of possibilities.

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ROLE OF MICROBES IN MICRO NUTRIENT UPTAKE

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Abstract
Soil micronutrient deficiencies present a substantial challenge to crop yields and human dietary intake, further complicated by the widespread use of nitrogen-phosphorus-potassium fertilizers and high-yielding crop strains. Traditional methods used in agriculture and genetics to increase the availability of micronutrients are often ineffective due to the low levels of essential elements such as iron (Fe) and zinc (Zn) available in the soil. Microbe-based solutions have the potential to address this issue by utilising plant-microbe interactions to mobilise and convert inaccessible micronutrients. The article in question examines microbial processes, including siderophore synthesis, release of organic acids, modification of root morphology, activation of nutrient transporters, the release of phenolic compounds, and mycorrhizal symbiosis, which collectively improve the uptake of micronutrients. Improving micronutrient bioavailability can be achieved sustainably by incorporating microbial inoculants into soil management systems, thereby addressing both crop yield limitations and the worldwide issue of Hidden Hunger. Despite the challenges of microbial efficacy, competition with native microorganisms, and scaling up, ongoing research and advancements in microbial formulations and plant-microbe interactions have a significant potential for enhancing crop nutrition through biofortification and supporting sustainable agricultural practices.

Keywords: Microbes, micronutrients, mobilization

Introduction

Growing crops in soils that naturally lack essential micronutrients poses considerable challenges. The Green Revolution's development worsened this issue, following the widespread adoption of NPK fertilizers that contained very few micronutrients. Crops with high yields that are grown in

rotation two or three times are contributing to the rapid depletion of micronutrients. Studies have found that the efficiency of micronutrient uptake from chemical fertilizers is surprisingly low, accounting for only 1-2% (Sekyere *et al*., 2021). The lack of essential nutrients has serious consequences, including diminished crop output and ultimately, a heightened risk of Hidden hunger - a condition with significant direct implications for people's well-being.

Three strategies have been identified to improve the absorption of micronutrients: agronomic methods, genetic enhancements and microbe-based approaches. Many soil micronutrients remain inaccessible. Realizing a crop variety's full genetic potential cannot be achievable through breeding strategies alone, as essential nutrients must be readily available in the soil. Microorganisms closely linked to plants, which are crucial for the biogeochemical cycling process, have potential for enhancing the nutritional value of staple crops through biofortification. Incorporating microorganisms into soil management techniques can convert inaccessibly available nutrients into a usable form by regulating the transport of certain nutrients, thereby supporting existing agricultural and genetic methods. The earth's crust contains significant reserves of iron (Fe) and zinc (Zn); however, these metals are primarily present in insoluble salt forms, thereby making them inaccessible to plant life. In soils lacking micronutrients, plants use natural methods, including the release of phytosiderophores, organic acids, or chelators, to access these essential nutrients. Recent breakthroughs in understanding the rhizosphere, the interface between soil, plant roots, and microorganisms, have brought to light mechanisms to enhance micronutrient absorption. This popular article examines mechanisms and techniques employing microbes to improve absorption.

Microbes in micronutrient mobilization & transformation

Microorganisms in the rhizosphere play a vital role in plant-soil interactions through four key steps: (1) active involvement in root-soil interactions, (2) mediating microbe-microbe and soil-microbe interactions, (3) direct root-microbe interactions facilitated by extensive signaling, and (4) a holistic interplay among root, soil, and rhizosphere microbiome.

Some examples for micro nutrient mobilizers

Iron mobilizers	Copper solubilizers	Manganese solubilizers	Zinc mobilization	Zinc solubilization	Molybdenum solubilizers
Bradyrhizobium japonicum, Rhizobium leguminosarum, Sinorhizobium meliloti, Pseudomonas, *Enterobacter*, *Rhodococcus, Clostridium*.	*Pseudomonas*, *Sphingomona, Bacillus*, *Arthrobacter, Stenotrophomonas.*	*Bacillus, Pseudomonas, Geobacter*, *Gaeumannomyces graminis*, *Acinetobacter sp.,*	*Burkholderia sp.*	*Glsuconacetobacter sp.*, *Acinetobacter sp.,Burkholderia sp.,Klebsiella sp.*, Ericoid mycorrhizal fungi *(Oidiodendron maius)*.	*Pseudomona, Bacillus, Leptothrix, Citrobacter, Acidobacteria , Firmicutes, Nitrospira, Chromobacterium,* and *Actinomyces*

Strategies for acquisition of Iron and Zinc

Mostly two strategies are there for acquisition of Fe and Zn in soils through microbes (Fig.1)

Strategy I - In plants from families like Liliaceae and Orchidaceae, primarily dicotyledons and non-gramineous monocotyledons, iron (Fe) solubility is enhanced via acidification and reduction mechanisms to address Fe deficiency. Protons are actively extruded into the rhizosphere using H^+-ATPase, lowering soil pH and converting ferric (Fe^{3+}) to the more soluble ferrous (Fe^{2+}) form.

Phenolic compounds from roots further boost ferric reduction at the root plasma membrane. Ferric chelate reductase in the outer membrane then reduces ferric to ferrous, which is absorbed by iron transporters.

Strategy II - Major cereal crops like rice, wheat, sorghum, and barley utilize a "chelation" strategy for iron (Fe) uptake, similar to mechanisms in bacteria and fungi. Plants produce phytosiderophores (PS), which belong to the mugineic acid (MA) class, to bind Fe^{3+} ions. These PS are secreted into the rhizosphere, where they form Fe^{3+}-PS complexes, which are absorbed by specialized root transporters.

MECHANISMS

1. Role of siderophores and other chelating substances

Low molecular weight peptides called siderophores have a high affinity for Fe (III), allowing for the iron availability by forming insoluble complexes with siderophores and Fe (III) in soil. Molecules formed through specialized metabolic pathways possess functional groups that exhibit a strong affinity for Fe^{+3} ions. In plants, mugenic acids in barley and nicotianamine in rice function as zinc chelators, whereas specific bacteria, including *Microbacterium saperdae*, *Pseudomonas monteilii*, and *Enterobacter*, produce zinc-binding metallophores.

Characteristics of Siderophores

1. These molecules exhibit a strong affinity for $Fe^{3+,}$ enabling its release from minerals and accelerating mineral dissolution.
2. These compounds exhibit high solubility and remain stable across a wide pH spectrum.
3. Plants receive assistance in transporting Zn and Fe.
4. Zinc-PS and iron-PS exhibit analogous architectures and control processes for biosynthesis and discharge in response to zinc or iron insufficiency.
5. Plants emit higher levels of PS in the early stages of light exposure, with lower output observed during prolonged illumination or darkness.
6. Plant stress production reaches its maximum level within three hours of when light begins, and then it gradually decreases.

2. Organic acid secretion and proton extrusion

Soil pH fluctuations greatly affect the availability of micronutrients, with minor increases significantly lowering their solubility. A one-unit increase in pH reduces zinc availability by a factor of 100 and iron availability by up to 1000 times. Microorganisms that produce organic acids significantly increase the availability of Fe and Zn in the rhizosphere, as these organic acids are crucial elements of root exudates that promote metal solubilization. This is achieved by plants through various means, including releasing protons and organic acids, which form soluble complexes with metal ions, and encouraging beneficial microbial growth in the rhizosphere.

Plants lacking essential nutrients frequently release larger quantities of organic acids, including citric, malic, succinic, fumaric, and oxalic acids, as well as acetic and formic acids. These acids facilitate nutrient absorption (e.g., phosphorus, iron, manganese) by binding to metal oxides (iron (III) oxide, manganese dioxide), thereby making them accessible to plant uptake. The process of protonation, caused by proton extrusion by roots, also decreases the pH of soil, thereby enhancing the availability of nutrients in alkaline soils.

3. Modification in root morphology & anatomy

The primary role of roots in nutrient absorption is enhanced by fine root growth and increased surface area, which are essential for the efficient uptake of immobile micronutrients, such as zinc.

Interactions between microorganisms, like the production of phytohormones and mycorrhizal infection promote root growth and nutrient acquisition. Endophytic bacteria enhance root structure, resulting in a 60-75% increase in Fe and Zn, as observed in rice studies. PGPB (plant growth promoting bacteria) improve nutrient absorption through changes to internal root structures, including altered cortex width and xylem vessel dimensions. Strains of *Arthrobacter sulfonivorans* DS-68 and *Arthrobacter* sp. DS-179, which produce siderophore and solubilize Zn, enhanced the accumulation of Fe and Zn in low Fe-Zn accumulator genotypes. A well-developed root system facilitated by microbial processes enhances the uptake and movement of essential nutrients.

4. Modulation of plant nutrient uptake systems and micronutrient transporters

Microorganisms such as endophytes and mycorrhizae increase plant nutrient absorption by controlling genes linked to Fe and Zn transport (Verma *et al*., 2021). Bacillus subtilis GB03 and *Paenibacillus polymyxa* BFKC01 triggered the activation of the FIT regulator in Arabidopsis, thereby increasing the expression of ferric chelate reductase (FRO) and the iron-regulated transporter (IRT1) to enhance iron absorption. In rice, Enterobacter cloacae increased zinc uptake by altering ZIP (ZRT, IRT-like protein) genes, whereas endophytes such as Arthrobacter enhanced TaZIP genes in wheat, thereby increasing absorption of iron and zinc (Singh et al., 2017). *Phomopsis liquidambari* caused an increase in iron accumulation in groundnuts by regulating the expression of the *FRO and IRT1 genes.* Wheat and barley absorb Fe and Zn through the release and transport of phyto-siderophores via yellow stripe-like proteins and ZIP transporters. Micronutrient transporters such as FRO, IRT1, ZIP, and FIT are involved, yet root-to-shoot micronutrient translocation remains a significant limitation.

5. Secretion of phenolics & related reducing moieties

Phenolic compounds in root exudates, which are crucial for dissolving nutrients such as iron and phosphorus from inaccessible sources, allowing plants to take them up (Verma *et al*., 2021). When plants are deficient in iron, dicot plants release these compounds to improve iron mobility in the soil. Alfalfa lacking iron releases the isoflavonoid phytoalexin [2-(3,5-dihydroxyphenyl)-5,6-dihydroxybenzofuran], which breaks down ferric phosphate to enhance iron and phosphorus availability while also serving as a defense mechanism against pathogens. Unlike plants with sufficient iron, those with this nutrient produce exudates that have a limited ability to solubilize nutrients. Tomato plants lacking iron release caffeic acid, allowing it to dissolve iron from insoluble sources under acidic conditions, using Strategy I for iron absorption.

6. Secretion of phytohormones like signaling molecules

Phytohormones such as gibberellic acid, cytokinins, auxins, nitric oxide (NO), ethylene, and brbrassinosteroidsegulate iron uptake by controlling genes such as IRT1 and FRO2. Auxins and ethylene serve as positive regulators of IRT1 and FRO2, thereby amplifying iron-deficiency responses in plants such as *Arabidopsis* and cucumber. Microbes in soil, such as Bacillus subtilis GB03, also trigger pathways related to iron deficiency, as reported by Xie *et al*. (2009).

Auxins, whether produced by microbes or applied from outside (for example, IAA, naphthaleneacetic acid), stimulate iron uptake by increasing FRO2 and IRT1 expression and promoting the growth of root hairs and lateral roots. Auxin-regulated processes that occur downstream are not involved in sensing iron deficiency; instead, they upregulate ferric chelate reductase activity through FIT-mediated FRO2 transcription, resulting in increased iron accumulation under iron-limited conditions.

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7. Mycorrhizal interactions with plants

Mycorrhizal associations in most plant species with fungi in 90% of cases, and these are vital for plant nutrition, with arbuscular mycorrhizae being the most prevalent type, primarily involving fungi from the Glomeromycota group. These fungi form appressoria to penetrate host root cortex cells, with an arbuscule formed where nutrient exchange occurs across both the periarbuscular and host cell membranes. In mycorrhizal networks, the expression of genes involved in nutrient transport, such as the cortical ZIP gene in *Medicago truncatula*, is downregulated. Mycorrhizal relationships supplement metal nutrition, with mycorrhizae responsible for approximately 20-50% of metal absorption and their function aided by metal transporters that are encoded by arbuscular mycorrhizal fungi.

Conclusion

To effectively tackle soil micronutrient deficiencies and their effects on crop yields and human health, integrated strategies must be employed. Biofortification through microbial methods which holds immense potential promise for sustainable food enrichment, even though agronomic and genetic approaches also have their advantages. We can enhance the availability of nutrients by leveraging the inherent capabilities of microorganisms, increase crop yields, and address the global problem of hidden hunger, worldwide. Unlocking the full potential of these methods necessitates further research and advancements in this field.

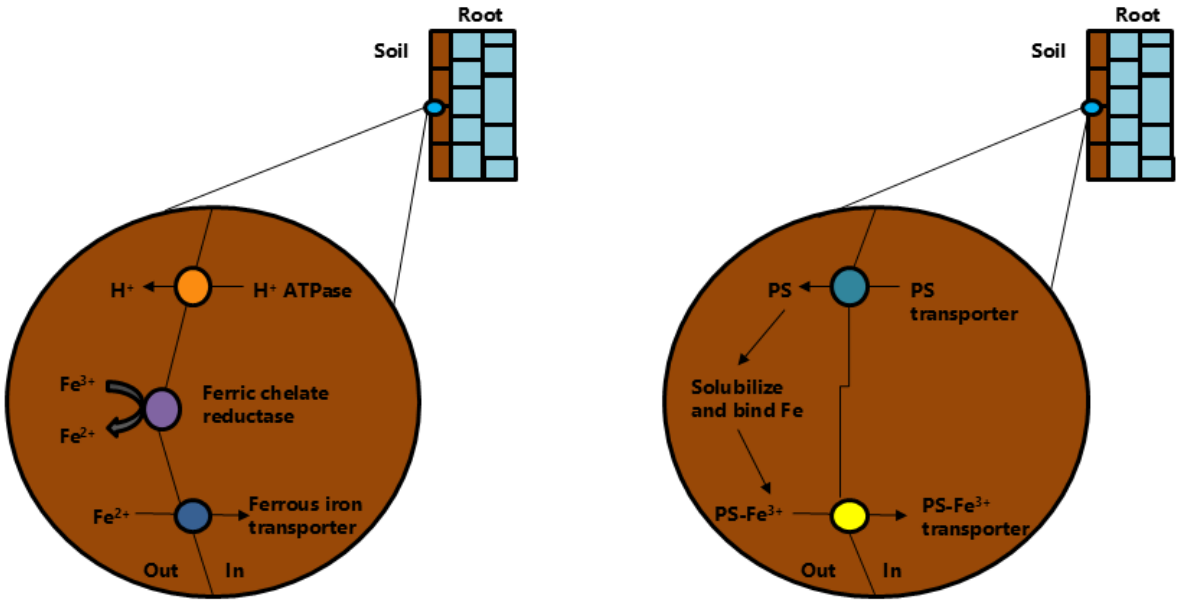

Fig.1. Strategies for acquisition of Fe and Zn in soils through microbes

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FUTURE PERSPECTIVE OF SEED BALL TECHNOLOGY FOR CREATING A NEW ECOSYSTEM

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Introduction

Seed ball technology is an ancient yet innovative method of reforestation and ecological restoration. This technique, originally credited to Masanobu Fukuoka, has gained renewed attention in the face of deforestation, climate change, and biodiversity loss. The future of seed ball technology lies in its potential to create sustainable ecosystems, enhance biodiversity, and contribute to large-scale afforestation efforts worldwide. This article explores the future perspectives of seed ball technology in ecosystem creation, its advancements, and its role in global ecological restoration.

Concept of Seed Ball Technology

Seed balls, also known as seed bombs, are small spheres composed of soil, clay, compost, and seeds. They serve as a protective medium for seeds, shielding them from harsh environmental conditions, pests, and birds until they germinate. This technique is particularly useful for barren lands, degraded forests, and urban green spaces where direct seeding might not be effective.

Future Applications of Seed Ball Technology

1. Large-Scale Reforestation and Carbon Sequestration

With rising concerns over deforestation and climate change, seed ball technology offers an efficient and cost-effective solution for large-scale reforestation. In the future, drones and AI-driven seed dispersal mechanisms could be used to drop seed balls over vast deforested areas, significantly reducing labor costs and time. These efforts will contribute to carbon sequestration and help mitigate the effects of global warming.

2. Restoring Degraded Ecosystems

Deforestation, overgrazing, and urbanization have led to the degradation of various ecosystems worldwide. Seed ball technology can play a pivotal role in reviving these lands by introducing native plant species and improving soil health. Scientists are exploring bioengineered seed balls that can contain soil enhancers, mycorrhizal fungi, and slow-release nutrients to support early plant growth.

3. Urban Greening and Sustainable Agriculture

In urban environments, seed balls can be used to enhance green spaces, rooftops, and community gardens. They can help restore urban biodiversity by introducing pollinator-friendly plants, medicinal herbs, and native vegetation. Furthermore, in sustainable agriculture, seed balls can be utilized for no-till farming, reducing soil erosion and preserving soil structure.

4. Combatting Desertification

Desertification is a pressing concern affecting many parts of the world. Future advancements in seed ball technology, such as moisture-retaining coatings and drought-resistant seed varieties, will enable

the reforestation of arid regions. Efforts in the Sahara, the Middle East, and Australia could benefit immensely from these innovations.

5. Biodiversity Conservation and Wildlife Habitat Restoration

Future developments in seed ball composition will allow for the strategic selection of plant species tailored to specific ecological needs. This will help restore wildlife habitats, ensuring that herbivores, pollinators, and other species have access to native flora. Ecologists and conservationists are exploring mixed-species seed balls that can create multilayered forests and diverse plant ecosystems.

Technological Advancements in Seed Ball Production and Deployment

1. AI and Drone Technology

The future of seed ball deployment is closely linked to AI and drone technology. Drones equipped with GPS and AI-driven sensors can accurately drop seed balls in areas requiring afforestation. Machine learning algorithms can analyze soil composition, rainfall patterns, and biodiversity indicators to determine the most effective planting strategies.

2. Smart Seed Balls

Innovations in seed ball composition will lead to "smart seed balls" that incorporate moisture-retaining gels, slow-release fertilizers, and microbial inoculants. These enhancements will ensure higher germination rates and better survival chances in harsh environments.

3. Biodegradable and Eco-Friendly Materials

The shift towards biodegradable and eco-friendly materials in seed ball production will make this technology more sustainable. Future seed balls may be wrapped in biodegradable biopolymers or natural fibers, reducing waste and ensuring that no harmful residues are left behind.

4. Genetic Engineering and Seed Enhancement

Genetic modifications and seed enhancements can improve the adaptability of plants introduced via seed balls. Scientists are exploring ways to develop climate-resilient plant species that can withstand extreme temperatures, droughts, and pests, making reforestation efforts more effective.

Indian Perspective on Seed Ball Technology

1. Role in Reforestation and Biodiversity Conservation

India, being one of the most biodiverse countries, faces challenges like deforestation, land degradation, and loss of native species. Seed ball technology is being increasingly adopted in various states as a cost-effective and scalable solution to restore forests. Government initiatives like "Green India Mission" and corporate social responsibility (CSR) programs have started using seed balls to promote afforestation efforts.

2. Application in Agriculture and Rural Development

Indian farmers, especially in arid and semi-arid regions, are utilizing seed balls to regenerate degraded lands. Seed balls containing drought-resistant crops and native grasses help improve soil fertility and reduce dependency on chemical fertilizers. NGOs and community-driven initiatives are also promoting the use of seed balls for improving the livelihoods of rural populations.

3. Addressing Desertification in India

Desertification is a growing concern in states like Rajasthan and Gujarat. Seed ball initiatives in these regions focus on planting hardy, native species that require minimal water. By leveraging drone

technology and traditional seed ball-making methods, India can significantly restore its degraded landscapes.

4. Urban Greening and Climate Resilience

With rapid urbanization, Indian cities are facing the challenge of declining green cover. Seed ball technology can be integrated into urban planning policies to promote green corridors, parks, and community gardens. This will not only enhance biodiversity but also improve air quality and mitigate urban heat island effects.

5. Government and Community Participation

Several Indian states have launched seed ball distribution programs involving schools, NGOs, and local communities. Awareness campaigns and workshops are helping citizens participate in ecological restoration efforts. Future policies could focus on subsidizing seed ball production and expanding partnerships between government agencies and environmental organizations.

Global Perspective on Seed Ball Technology

Case Study: Seed Ball Reforestation in Thailand

In Thailand, the government and environmental organizations have employed seed ball technology to restore deforested areas, particularly in the northern regions. The "Royal Project Foundation," initiated by King Bhumibol Adulyadej, has supported the use of seed balls to rehabilitate degraded land. Local communities and volunteers have contributed to dispersing seed balls containing native tree species such as teak and dipterocarps, which play a crucial role in maintaining Thailand's rich biodiversity. This initiative has demonstrated the effectiveness of seed balls in tropical climates.

Case Study: Seed Ball Reforestation in Kenya

Kenya has been facing significant deforestation due to agricultural expansion and logging. To combat this, NGOs and environmental groups have launched seed ball reforestation programs. The "Seedballs Kenya" initiative has distributed millions of seed balls containing native tree species like acacia and baobab. By leveraging drone technology and community involvement, this initiative has successfully restored thousands of hectares of degraded land, proving the efficacy of seed ball technology in large-scale afforestation efforts.

Countries worldwide are recognizing the potential of seed ball technology in combating deforestation and restoring ecosystems. Africa's Great Green Wall initiative has adopted seed balls to combat desertification across the Sahel region. Similarly, Australia has been experimenting with aerial seed ball dispersal to reforest fire-ravaged landscapes. In South America, Brazil's Amazon reforestation programs are integrating seed ball techniques to restore degraded rainforest areas. The global adoption of seed ball technology underscores its effectiveness as an affordable and scalable ecological restoration method.

Challenges and Future Solutions

1. Seed Viability and Germination Rates

One of the key challenges of seed ball technology is ensuring high germination rates. Future research will focus on optimizing seed coatings, microbial symbiosis, and soil amendments to improve viability.

2. Scalability and Cost Effectiveness

For seed ball technology to become a mainstream solution, it must be cost-effective and scalable. Governments and private sectors need to invest in mechanized seed ball production and deployment systems to make large-scale applications feasible.

3. Ecosystem-Specific Customization

Different ecosystems require tailored approaches. Scientists and conservationists will need to develop region-specific seed ball formulations to ensure that introduced plant species thrive and integrate seamlessly into existing ecosystems.

Conclusion

Seed ball technology has the potential to revolutionize afforestation, urban greening, and ecosystem restoration. As technological advancements improve seed viability, deployment efficiency, and ecological customization, the future of seed ball technology looks promising. By integrating AI, drone technology, and biodegradable materials, this method can play a crucial role in creating new ecosystems and combating global environmental challenges. With continuous research and investment, seed ball technology can contribute significantly to a greener and more sustainable planet, particularly in a diverse and ecologically rich country like India.

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MICROBES IN AGRICULTURAL PRODUCTIVITY

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Abstract

Microorganisms are the unseen major part of soil and make a huge part of life genetic diversity. They are responsible for the maintenance of soil structure and sustainability of soil quality for efficient plant growth. Soil microbes play a significant role in regulating plant productivity, soil health, especially in nutrient poor environment where plant symbionts are responsible for acquiring limiting nutrients. Microorganism helps by stimulating biological activity and enhancing interaction between the soil and plants. Free living microbes also strongly regulate plant productivity through mineralization and competition for nutrients that sustain plant productivity. The use of both organic manures and biofertilizers in combination is one method for enhancing the soil fertility. Biofertilizers are microbial inoculants of bacteria, fungi, actinomycetes, and protozoa that can fix nitrogen, phosphate, and can solubilize or break down organic matter while balancing the biological balance in the soil. The fertility of the soil is influenced by a variety of microorganism species that effect the quantitative composition of the soil in addition to the presence of inorganic and organic matter.

Keywords: Soil microbes, Soil heath, Crop yield, Soil fertility, Zero hunger

Introduction

Microbes are present in every aspect of agriculture as there are few helpful microbes .including bacteria, actinomycetes, fungus and protozoa the majority of the microorganism found in compost are bacteria. In soil, there is a more prevalent group of microbes, including *Arthobacter*, *Bacillus*, *Clostridium* and *Micrococcus*. On the other hand, molds and yeast, which are fungi, assist bacteria in breaking down compounds such as lignin in woody materials. They make the soil better and create favourable environments for plant growth. Soil microbes act as biochemical agent as they transform complex organic compounds into simple inorganic compounds or their component elements. Microorganisms help in organic matter decomposition thus leading to humus formation. The main important role of microorganism includes nitrogen fixation, phosphate solubilization, potassium mobilization, antagonism towards pathogens and pests. Hence, the role of microorganisms in agriculture is indispensable.

Other important roles in agriculture:

1. Microorganisms enhance soil fertility. Certain microbes, such as bacteria, are proficient decomposers, effectively breaking down decaying organic matter. This material, when combined with the soil, will enhance its fertility
2. Some microorganism like *Rhizobium* form symbiotic association with plants and form root nodules. These organisms fix atmospheric nitrogen and supply it to plant
3. Biological fertilizers obtained from microorganisms are good in improving soil quality and fertility. They are also environmentally friendly and do not cause any toxic or dangerous effects
4. *Rhizobium*, *Azotobacter*, *Azospirillum* and *Mycorrhiza* acts as biofertilizer

5. Microorganisms such as filamentous fungi play an important role in soil agglomeration (process of forming clusters or aggregates of soil particles, which can improve soil structure, fertility, and overall health)
6. Microorganisms play an important role in the nutrients cycle
7. Some bacteria (Plant growth promoting bacteria) secrete phytochemical and organic acids that are helpful in the growth and development of plants.
8. Microorganisms help maintain soil pH but balance nutrients and minerals

Types of Microbes:

a) Bacteria: Bacteria decompose dead organic matter and releases simple compounds in the soil which can be taken up by plants.

i. **Nitrogen fixing bacteria (NFB):** Nitrogen-fixing bacteria are important in agriculture because they help plants grow by fixing nitrogen and producing phytohormones.
Eg. *Rhizobium* and *Bradyrhizobium*.

ii. **Phosphorus solubilizing bacteria (PSB):** These microorganisms that help plants absorb phosphorus (P) by converting insoluble phosphate into a soluble form.
Eg. *Peudomonas*, *Bacillus*, *Micrococcus*, *Aspergillus* and *Fusarium*.

iii. **Zinc solubilizing bacteria (ZSB):** These types of bacteria that can make zinc available to plants by converting it form insoluble to more accessible form. They can be found in the rhizosphere soils of plants such as peanuts and sweet potatoes.
Eg. Acinetobacter , Bacillus sp, Pseudomonas sp.

iv. **Potassium solubilizing bacteria (PSB):** These microorganisms solubilize the insoluble potassium to soluble form of K for plant growth and yield. Eg. *Bacillus mucilaginosus*, *Bacillus edaphicus*.

b) Fungi: Fungi play a vital role in improving plant nutrition, and productivity. There is an ecological plant microbe interaction where the microbes along with plants regulate several soil processes as well as the carbon cycle and nutrients utilization.

i. **Vesicular arbuscular mycorrhiza**: VAM is a symbiotic relationship between a fungus and a plants root that helps the plant grow and develop. VAM is an obligate symbiont and they cannot be cultured in nutrient medium. They help in plant growth through their hyphae that absorb phosphorus from the labile pool.

ii. **Edible fungi**: Edible fungi are a kind of large fungus that can form large fleshy or colloidal of fruit bodies or sclerotia tissues. They have long been used as food and folk medicine in different parts of the world due to their nutritional composition, pleasant taste and flavour.

c) Virus: Viruses can help plants survive biotic and abiotic stresses under certain conditions. In addition, viruses can interact with bacteria, weed, pathogenic and symbiotic fungi, insect pollinators and other species in ways that benefit or harm final crop production.

d) Protozoa: Protozoa are acellular, microscopic organisms found everywhere, in water, soil on the body of plant, animal, etc. They help in crop production through

i. **Pest control**: Some protozoa are natural predators of soil-dwelling pests and pathogens. They can help manage harmful organisms that might otherwise damage crops.

ii. **Soil structure**: Protozoa contribute to the formation and stabilization of soil aggregates. Their activities can help improve soil structure, enhancing water infiltration and reducing erosion.

iii. **Soil health**: Protozoa help maintain soil health by decomposing organic matter and contributing to nutrient recycling.

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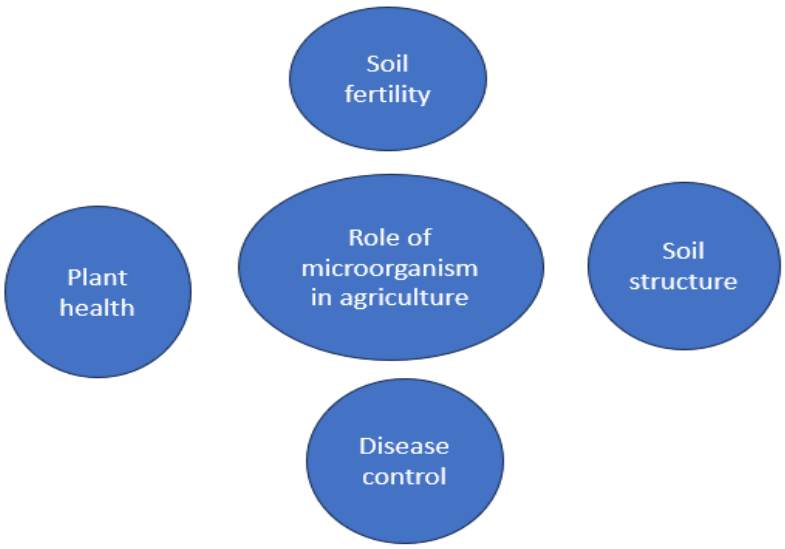
Role of microbes in agricultural productivity

1. **Soil fertility -** Soil fertility refers to the ability of soil to provide essential nutrients to plants for their growth. **Nutrient Content**: Essential nutrients like nitrogen, phosphorus, and potassium must be present in adequate amount. **Soil pH** : The acidity or alkalinity of the soil affects nutrients availability. **Soil Structure**: well structured soil with good aeration and drainage supports root growth and nutrients uptake.
2. **Plant health -** Plant health is essential for optimal growth and productivity. **Nutrients supply**: Plants need a balanced supply of essential nutrients (nitrogen, phosphorus, potassium and micronutrients) for healthy growth. **Water Management**: Adequate and timely watering is crucial; both overwatering and underwatering can cause stress to plants. **Soil quality**: Good soil structure, fertility, and proper pH levels support plant health.
3. **Soil structure -** Soil structure refers to the arrangement of soil particles into aggregates or clumps. **Aeration**: Well structure soil allows for proper air exchange between soil and roots which is vital for root respiration and overall plant health. **Water Infiltration and Drainage**: Good soil structure promotes better water infiltration and reduces the risk of water-logging or erosion. **Root Growth**: Aggregates in well structured soil provide space for roots to grow and access nutrients more easily.



Conclusion

Microbes play a pivotal role in enhancing agricultural productivity, and their potential in this regard cannot be overstated. By harnessing the power of beneficial microorganisms, farmers can improve crop yields, enhance soil fertility, and promote ecosystem services. The use of microbes in agriculture offers a sustainable and eco-friendly solution to the challenges facing modern agriculture, including climate change, soil degradation, and water scarcity. In order to fully harness the potential of microbes in agriculture, further research is needed to improve our understanding of the complex interactions between microorganisms, plants, and the environment. Additionally, the development of effective and efficient methods for the application of microbes in agriculture is crucial.

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A REVIEW OF HARAD : (*Terminalia chebula*)

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Introduction

The Combretaceae family includes the medium- to large-sized *Terminalia chebula* tree, which is found all over Asia. In India and Southeast Asia, this versatile medicinal agroforestry tree species is widely used as a herbal cure. To treat many illnesses, traditional homeopathic and unani medicines use all parts of the tree. 'Haritaki/Myrobalan,' another name for *Terminalia chebula*, has long been used as a traditional medicine. The 'King of Medicine' is the name given to *T. chebula*. It's known as 'haritaki' since it is dedicated to the god Shiva (Hara) or diverts all symptoms. Numerous traditional medical disciplines, including Unani, Tibb, Ayurveda, and Siddha, have made substantial use of it to treat human maladies like bleeding, digestive issues, liver tonic, carminative, dysentery, analgesic, anthelmintic, antibacterial, and skin conditions. It is a flowering evergreen tree, and traditional folk medicine makes extensive use of its leaves, fruits, seeds, and bark. Antibacterial, antifungal, anti-carcinogenic, antioxidant, antidiabetic, anti-inflammatory, anti-HIV, and anti- aging properties are all possessed by this plant. Bioactive substances such as tannins, flavonoids, sterols, amino acids, fructose, and resins are abundant in *T. chebula*. Nevertheless, the application might be due to tannins such as ellagic acid, gallic acid, chebulinic acid, chebulagic acid, and corilagin. Different phytoactive substances were detected in one-third of the samples.

Botanical description:

Terminalia chebula is a medium to large deciduous tree growing 25-30 m (98 ft) tall, with a trunk up to 1 m (3 ft 3 in) in diameter. The seed is globose and 2-6 cm long, sometimes tapering towards the lower extremity, obscurely 5 or 6 sided, more or less furrowed longitudinally, covered with a smooth yellowish-brown epidermis, within which is an astringent pulp, enclosing a large rough bony one celled endocarp. The leaves are alternate to subopposite in arrangement, oval, 7–8 cm (2.8–3.1 in) long and 4.5–10 cm (1.8–3.9 in) broad with a 1–3 cm (0.39–1.18 in) petiole. They have an acute tip, cordate at the base, margins entire, and glabrous above with a yellowish pubescence below. The dull white to yellow flowers are monoecious, and have a strong, unpleasant odor. They are borne in terminal spikes or short panicles. The fruit is drupe-like, smooth ellipsoid to ovoid, 2–4.5 cm (0.79–1.77 in) long and 1.2–2.5 cm (0.47–0.98 in) broad, blackish, with five longitudinal ridges. They are yellow to orange-brown in color, with a single angled stone. Haritaki fruit has laxative, carminative, astringent, expectorant, and tonic properties in Ayurvedic medicine. Fever, cough, diarrhea, gastroenteritis, skin problems, candidiasis, urinary tract infection, and wound infections are only a few of the ailments for which Tamil Nadu tribes employ it as traditional medicine. It's a diuretic and cardiotonic found in several Ayurvedic formulations. It's used to help you live longer and have greater energy and immunity. It is reported to be capable of curing blindness and slowing the progression of malignant tumors. The mean maximum temperature in its habitat varies from 37°C to 48°C, the absolute minimum temperature from 1°C to 15°C and annual rainfall from 750 to 3250 mm.

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Fig 1. Leaves

Fig 2. Bark

Fig 3. Fruits

Distribution

Terminalia chebula is found throughout southern and southeast Asia, including in India, Sri Lanka, Bhutan, Nepal, Bangladesh, Myanmar, Cambodia, Laos, Vietnam, Indonesia, Malaysia, Pakistan, and Thailand. In China, it is native in western Yunnan and cultivated in Fujian, Guangdong, Guangxi (Nanning), and Taiwan (Nantou). *Terminalia chebula* is an important medicinal plant in Indian traditional medicine, and it is the most frequently used herb in Ayurveda. *Terminalia chebula* is a medium- to large- sized tree distributed throughout tropical and subtropical Asia, including China and Tibet. This tree is found in the forests of northern India, Uttar Pradesh, and Bengal, and is common in Tamil Nadu, Karnataka, and southern Maharashtra. *Terminalia chebula* is commonly known as black myroblans in English and harad in Hindi. The Terminalia consists of 250 species and is widely distributed in tropical areas of the world.14. The fruit of *Terminalia chebula* is considered the "king of medicines" by Tibetans and second to none by Ayurvedic apothecaries and is also held in high regard by other folk medicinal practitioners.

Silvicultural regeneration: Natural regeneration of *T. chebula* form seeds in situ and ex situ is extremely low and is a slow growing tree compared to other species of Terminalia. In situ propagation has also been developed. Direct sowing seeds results in queer, inadequate germination and low survival of seedlings, all of which contribute to high production cost of seedling stock. Micropropagation of *T. chebula* has already been reported form shoot buds of mature trees. Reports on induction of callus are also there.

Propagation

It grows on a variety of soils but thrives best in clay and sandy soil. The fruits ripen from November to March depending upon the locality. Mostly fallen fruits are collected in the first half of January; they are dried, and the seeds can be stored for one year. Seed germination is low because of the hard cover, and the seed requires pre-sowing treatment. Best germination is obtained when the seeds are chipped at their broad end without damaging the embryo and then soaked in water for 36 h before sowing in nursery beds. Germination starts after 15 days and continues for 3-4 weeks. The tree can be successfully raised by directly sowing the seed or, by transplanting the seedlings, or by stem cuttings. It is observed that transplanting of 1-year seedling grows better than cutting or direct seed- sown plants. The young plant requires watering during the first hot weather. Shelter is desirable. The general growth of plants is slow.

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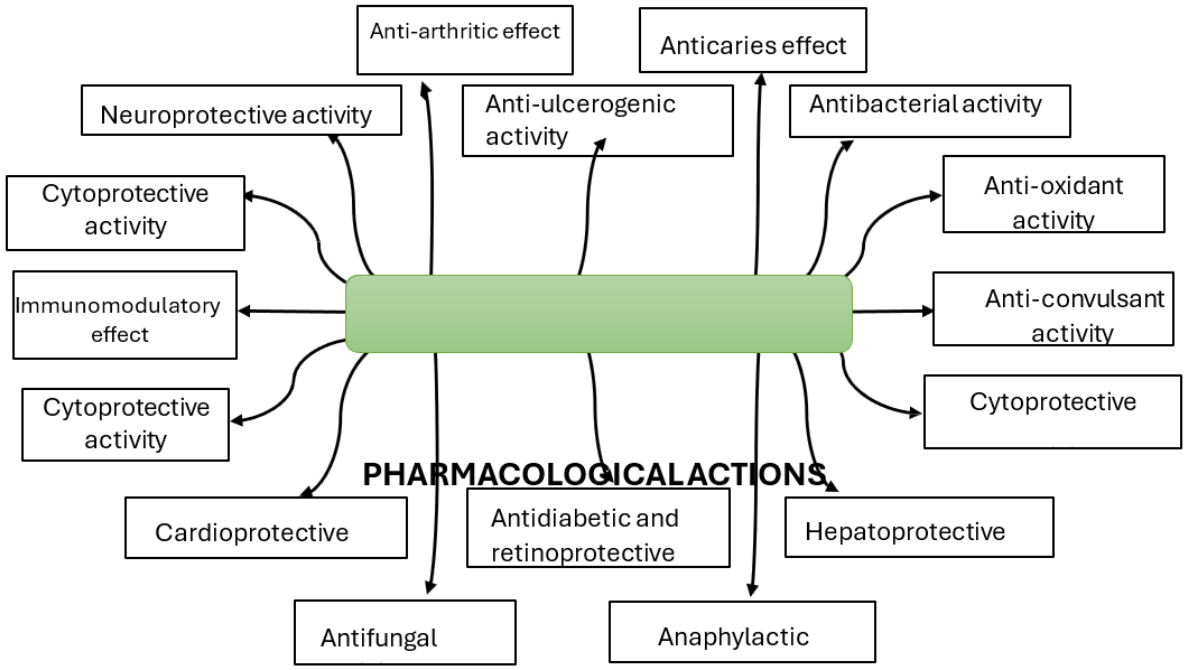

Medicinal value of *Terminalia chebula:*

Terminalia chebula, an Indian herb, is largely used in the Ayurvedic system of medicine for its homeostatic, antitussive, laxative, diuretic, and cardiotonic activities. It is an important vegetable tanning material and has been used for ages in India. The dried fruit is used as a tonic, in hepatic and spleen enlargements, and in skin diseases. Its paste with water is anti- inflammatory, analgesic, and has purifying and healing properties for wounds. Its powder is also used as an astringent and dentifrice for loose gums. The chebulic acid from *Terminalia chebula* fruit has antispasmodic action, increasing appetite and acting as a digestive aid. It promotes the receiving power of five senses and is used as a gargle for chronic coughs, sore throats, dysuria, and skin disorders. It also reduces the impact of rich fatty, creamy, and oily foods and supplements cholesterol- normalizing drugs.

Present status of *Terminalia chebula*:

Terminalia chebula and *Terminalia bellerica* are both used for high cholesterol and digestive disorders, including both diarrhea and constipation and indigestion.

They have also been used for HIV infection. *Terminalia chebula* is used for dysentery. They both are used for sore eyes. *Terminalia chebula* is also used topically as a mouthwash and gargle. Intravaginally, *Terminalia chebula* is used as a douche for treating vaginal infections. In traditional Ayurvedic medicine, *Terminalia bellerica* is also used as a "health- harmonizer" in combination with *Terminalia chebula* and *Emblica officinalis*. This combination is also used to lower cholesterol and to prevent death of heart tissue**.**

Economic importance of *Terminalia chebula:*

Production and Marketing India is by far the main producing country of Harar. Production of dried fruits in India is estimated to be 100,000 tonnes, of which 20% is exported to adjoining countries, Europe, and the U.S. (World Agroforestry Centre). Large-sized fruits fetch a higher price in the national and international markets, and thus fruit size is an important characteristic. Harar that is

freshly collected and dried immediately has a yellowish color and fetches a better price. The demand for its fruit has increased tremendously because of its medicinal value; its fruits are sold at a price of 10 to 60 kg-1. The Harar produced in Morni Hills and the adjoining part of Haryana is in great demand in Pakistan, Afghanistan, Iran, Iraq, and other Gulf countries. The Harar fruits are sold at two places (Khari Bawali in New Delhi and Majitha in Amritsar district) in North India. In South India, Coimbatore, Mumbai, Chennai, Nagpur, Bangalore, and Indore are the major markets of Harar.

Conclusion

It is also used as one of the most important medicinal plants in Siddha, Unani, and homeopathy because it has several medicinal properties. It is the source of a variety of bioactive phytoconstituents such as flavonoids, sterols, amino acids, and tannins; chebulic acid, chebulinic acid, chebulagic acid, gallic acid, and other related compounds that are responsible for different pharmacological activities like antimicrobial, antioxidant, antibacterial, antidiabetic, hepatoprotective, anti- inflammatory, and anticarcinogenic, etc. *Terminalia Chebula* has a strong effect against wound healing, has antibacterial activity, and exhibits strong cardioprotective properties. *Terminalia Chebula* also has antioxidant components, which indicates it can increase the life of tissues. A few studies show the anti-tumor activity of *Terminalia Chebula*, and another study shows that it has a considerable effect in inhibiting the HIV virus, which ultimately results in AIDS. There is substantial evidence found that it can be used as a gastrointestinal motility agent and an anti-aging substance. It also possesses properties like antilithiatic activity, hypolipidemic activity, radio-protecting ability, antifungal activity, and etc.

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TURKEY FARMING: A PROSPEROUS ADDITION IN INDIAN POULTRY SECTOR

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Introduction

In world demographics the current human population stands for 8.2 billion and it is expected to cross 9.7 billion in 2050 and India surge first in population growth (. To meet the protein requirement by meat and egg of this huge population, poultry sector is playing a great role. Among the various poultry species chicken is contributing around 90% but there are some lacunae in the production and requirement of egg and meat. For this reason, now a days various researches are going on diversified poultry species in which turkey farming having a great importance. Turkeys can be a valuable and versatile addition to both commercial and small scale poultry farming. Turkey (*Meleagris Gallopavo*), the native of North America and domesticated in Europe, is a large gallinaceous bird of the family *Meleagridae* which is playing a significant role in augmenting the nutritional and economic status of varied population in all over the world.

In western countries turkey farming is very popular and United States of America, Canada, Germany, France, Italy, Netherlands and the United Kingdom are the major turkey producing countries. Central Poultry Development Organization (Southern Region) Hesaraghatta, Bangalore has made serious efforts to promote turkey farming in India. Currently the turkey farming is growing in India with the rate of 135%. Some indigenous or non-descriptive type of turkeys are found in eastern districts of Uttar Pradesh, Kerala, Tamil Nadu and some other parts of India among which Kerala and Tamil Nadu are the leading states in turkey farming. ICAR-CARI, TANUVAS, Central Poultry breeding farm-Hesaraghatta and some agricultural universities are in the frontline of turkey farming and breeding. They are mostly reared for the purpose of meat and its leanest meat is having high nutritious value. The fat, protein, energy value of turkey meat is 6.6%, 24%, 162 Calories per 100 gm of meat respectively. Turkey meat having unsaturated and essential fatty acids, low cholesterol, niacin, vitamin B6 and B12 and rich mineral source. Not only meat, but the egg of turkey is also nutritious having protein, lipid, carbohydrate and mineral content of turkey egg are 13.1%, 11.8%,1.7% and 0.8% respectively with cholesterol of 15.67-23.97 mg/gm of yolk.

Keywords : Turkey, ICAR-CARI, Poultry farming, leanest meat

Breeds and varieties of turkey

Big six, Hybrid large white, Nicholas 900 & 700 and BUT-8, BUT-9, Big-9, hybrid super medium, Nicolas 300 are the various heavy and medium type of turkey breed in the world. Generally, turkeys are not classified into breeds, however seven standard varieties are there named Bronze, White Holland, Bourbon red, Narragansett, Black, Slate, Beltsville small white. In India various agricultural and veterinary research institutes has improved several turkey varieties. In Indian-Agro climatic conditions White plumage *turkeys are* seem to be suitable due to better heat tolerance capacity.

Table: -1- Indian Turkey varieties and their characters

Name of varieties	Cross	Characters	Poult price	Fertile egg price	Developing institute and its location
CARI VIRAT	Turkey mixed	i. Low fat, cholesterol ii. High protein iii. Suitable for backyard farming iv. Body wt. 7-7.1 kg at 32 wks v. Plumage is white in colour	<u>For parent stock (Pure line)</u> Day old Poult- Rs.65/chick. 5-6 weeks old poult - Rs.190/poult. 13- 16 weeks old poult- Rs.600/poult. >16 weeks (male& female) - Rs.180/Kg. Adult stock- Rs.1000/male & 800 / female.	<u>For parent stock (Pure line)</u> Fertile egg- Rs. 50/egg Embryonated egg- Rs.55/egg	ICAR-Central Avian Research institute, Izzatnagar, Bareilly, UP 243122
CARI BLACK	_	i. Black plumage colour ii. Weight of day old poult 47-55 gm iii. high immunity			
CARI CHITLA	_	i. Black and white spotted plumage colour ii. Day old poult weight is 48-56 gm			
NANDANAM TURKEY 1	Black desi and exotic Beltsville small white variety	i. Attractive black and white plumage ii. Better disease resistant iii. High egg production with better hatchability iv. Desirable meat flavor v. Suitable for backyard farming	One month old poults Rs.150 to 175 /poult	_	Tamil Nadu Veterinary and Animal Sciences University (TANUVAS), Madhavaram milk colony , Chennai-600051, Tamil Nadu India

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Name of varieties	Cross	Characters	Poult price	Fertile egg price	Developing institute and its location
NANDANAM TURKEY II	Improved variety of Beltsville small white	i. Market wt. of 3020 gm at 16 th week ii. Livability (95%) iii. High carcass yield (75.36%) iv. Egg production-70 eggs at 24-44 weeks v. Suitable for backyard farming			

Sexual dimorphism

In turkeys, vent sexing is generally not in practice. Mature male turkey or toms are heavier, have black bread attached to the skin of the upper breast region, dew bill or snood on beak base, caruncles on head whereas in female hen turkey dew bill or snood is relatively small, bread and caruncles are absent. Adult male turkey is known as Tom whereas adult female is known as Hen and young one of turkey is known as poult. Mating behavior of male turkey is called strutting. Hens start laying from the 30th week of age and its production period is 24 weeks and number of eggs laid 60-100 eggs annually having about 85 gms of wt. Eggs are hard shelled(0.3-0.4mm) and spotted.


CARI CHITLA


CARI VIRAT


CARI BLACK


Turkey eggs (spotted)

Fig: -Turkey farming in ICAR- Central Avian Research Institute, Izzatnagar

Managemental aspects of turkey farming

1. Poult management

a) Incubation : The incubation period in turkey is 28 days. In natural incubation good broody hen can hatch nearly 10-15 numbers of eggs. In artificial incubation, temperature in setter and hatcher is 99.5^0F whereas relative humidity in setter and hatcher is 61-63% and 85-90% respectively. The average weight of a day old poult is around 50gm

b) Brooding : In case of turkey brooding period is4 weeks normally but may be extended upto 5-6 weeks in winter. Requirement of space is 1.5 sq.ft. per bird,

c) Debeaking : The poults are generally debeaked at about one half the distance from nostril to the tip of the beakto control feather picking and cannibalism at day old or 3-5 weeks of age .
d) Detoeing or toe clipping : It is the practice of removal of the tip of toe just to the inside of the outer most toe pad including the entire toenail.at day old.
e) Vaccination and deworming : At day old age ND – B1 strain, at 4th & 5th week Fowl pox, 6th week ND – (R2B) and at 8 to 10 week Cholera vaccine can be given. As turkey birds in free range system are highly susceptible for internal and external parasites, deworming and dipping is essential once in a month.

2. Housing management

- Free range system: - About 200-250 adult turkeys can be reared in one acre of fenced land and each bird requires around 3-4 sq.ft. space. This rearing system can reduce the feed cost by fifty percent.
- Intensive system: - In this system, long axis of the house should run from east to west in hotter regions to prevent direct sunlight and the distance between two houses should be at least 20 meters. Management and disease control are relatively better in this system leads to improved production efficiency.In deep litter system of rearing the general managemental conditions are nearly similar to that of chicken.

3. Feeding management

Mash feeding and pellet feeding are most commonly practiced. Nutrient requirements for turkeys are higher in comparison of chicken. Generally turkey is less sensitive to dietary energy level but require more protein (28% CP) and amino acids at earlier part of life. 2900-3300ME/kg diet energy and 16-28 % crude protein is required per bird along with other nutrients and Feed efficiency is 2.7 -2.8. Breeders requires lower level of protein (14% CP). Turkeys are very good scavengers so it can consume small insects, earthworms, kitchen waste, snails and termites in free range system. Greens like fresh lucerne can be fed upto 50% of the total diet on dry mash basis in intensive system.A practice like force feeding in poults is practiced to eliminate the starve out problem, in which milk is fed at 100ml per liter of water and a boiled egg have to be given at the rate of one per 10 poults up to fifteen days.

4. Breeding management

In natural mating, male: female ratio is 1:3 for large types whereas 1:5 for medium type turkey's birds. As toms have a possibility to develop affinity towards a particular female, there is a practice to change the toms for every 15 days in a particular mating flock. Due to the heavy weight of tom, natural mating may become problematic sometimes. To maintain high fertility throughout the season, artificial insemination is mostly practiced.Semen is collected from tom at the age of 32-36 weeks, having high concentration and low volume.When the female turkey or hens attains 8-10% egg production,they are inseminated with 0.025-0.030ml of undiluted semen of atleast 80-85% motility at every three weeks. Generally, insemination is done in the eveningafter 5-6' O clock.

5. Disease management

Though turkeys are resistant to several disease conditions to which chickens are severely susceptible, Turkeys may suffer from Arizonosis, Blue comb disease, Haemorrhagic enteritis and Chronic respiratory disease etc, needs proper preventive measures and vaccination .Strict biosecurity, proper sanitation, vaccination and Vitamin E and C supplementation are some

preventive measures during the time of disease outbreak. Tiamutin at the recommended dose can be given for three days in a month in turkeys to prevent the occurrence of *Mycoplasma* infections.

Marketing of turkey birds

The marketable age for tom and turkey hen is 14 -15 weeks and 17 – 18 weeks respectively. The optimum marketing body weight of tom is 7.26 kg whereas for hen turkey 5.53kg respectively. The demand for turkey is mostly seasonal specially during Christmas, New year and Easter. Toms are sold at 24 weeks of age having weight of 10 to 20 kg; give a profit of Rs 500 to 600 where the expenditure is of Rs.300 to 450.

Future prospective of Turkey Farming

Turkey farming is becoming popular day by day in the country and has a good potential specially where people have lean meat preference and christian dominating areas. Being resistant to multiple diseases and suitable for free range and intensive rearing system, it can be used as an entrepreneurship. Various government projects are coming to produce improved variety of turkey, breeding programme and for the extension of the good turkey farming practices country wide.

Conclusion

According to various research studies, it has been observed that turkey farming can become a very important segment of Indian poultry sector. Though turkey farming in the country is a scattered type of farming still now, with the help of Government and various poultry research institutes, turkey farming may become a renowned employment generating and livelihood providing farming sector contributing to the country's economic growth.

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UNLOCKING THE RURAL POTENTIAL : SEED VILLAGE PROGRAMME

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Abstract
Seeds are the fundament of agriculture. High-quality seeds serve as an indispensable input for maximising productivity, leading to an increase in crop yield by 15-20 %. The adoption of quality seeds addresses key food security issues while improving farmers' livelihoods. However, despite the popularization of quality seeds, small and marginal farmers frequently rely on farm-saved seeds, which are of inferior quality. The use of inferior seeds contributes to low yield, underscoring the need for accessibility to quality seeds. Regardless of the implementation of seed programmes, a significant gap remains evident between the demand and availability of quality seeds. Hence, the Seed Village Programme aims to address the challenge by focusing on self-sufficiency in seed production and distribution at the grassroots level. The notion of Seed Village not only increases farmers' income but also offers opportunities to improve agricultural production by ensuring the timely availability of quality seeds at the farmers' doorsteps.

Keywords : Seed Village Programme, quality seed, seed production, productivity

Introduction

Quality seeds play a critical role in increasing production, yield and profit. Quality seeds alone can boost yields by 15-20 %. However, in India, there exists a persistent challenge to access to sufficient quantity of quality seeds during planting seasons. Regardless of the establishment of coordinated seed programs since the middle of the 1960s, the Seed Replacement Rate (SRR) has remained at about 20%, while the target SRR is 33% in India (Bhavani *et al*., 2022). The remaining 80% of the required seeds are handled by using farmers' farm-saved seeds. The continued use of farmer-saved seeds promotes genetic deterioration of the seeds, resulting in decreased productivity and plant vigour within two to three years; thus, farmers must substitute farm-saved seeds with certified seeds to preserve yield and vigour. While the government's seed production capacity is limited, private sector seeds are only exclusive for a few specific crops with sky-high prices, worsening the scarcity and making it unfavourable for small landholding farmers. Hence, it is vital to increase the stock of quality seeds so that they are readily available throughout the sowing season at lower prices. To deliver high-quality seeds to smallholder farmers at affordable prices, the government employs decentralized seed production and distribution through the Seed Village Programme, to reduce reliance on external sources and promote local seed production self-sufficiency.

The Seed Village Programme (SVP)

The SVP has been implemented since the 1960s under several institutions including State Departments of Agriculture (SDA), State Agriculture Universities (SAU), Krishi Vigyan Kendras (KVK),

the Indian Council of Agricultural Research (ICAR), and others. However, the SVP also referred to as the Bheej Gram Yojana (SVP/BGY), gained vital importance and relevance when it began to be implemented under the sub-components of the sub-mission on Seeds and Planting Materials (SMSP) under the National Mission on Agricultural Extension and Technology (NMAET) in 2014-2015 and is currently being implemented under the National Food Security Mission (NFSM) since 2018 (Bhuvana *et al*., 2023). Through the Programme, government-run State Seed Farms produce foundation seeds, which are traceable to breeder seeds, and supply them to farmers at a 50% subsidy, enabling them to produce high-quality certified seeds for sale to local farmers, promoting seed authenticity and quality.

A Seed Village is a group of trained farmers who produce quality seeds for diverse crops on an informal basis, who not only meet their seed requirements but also assist fellow farmers in the community and neighbouring villages by providing timely and adequate accessibility to the seeds that they produce (Bordolui *et al*., 2020). Seed villages are set up based on favourable weather conditions and local seed demand, with each village encompassing about twenty-five acres (10 ha) and including at least fifty farmers to overcome the quality seed supply gap. Farmers receive training on critical crop stages and are offered subsidies for seed storage bins, processing machinery, and cleaning, packaging, and distribution, to support the production and supply of high-quality seeds.

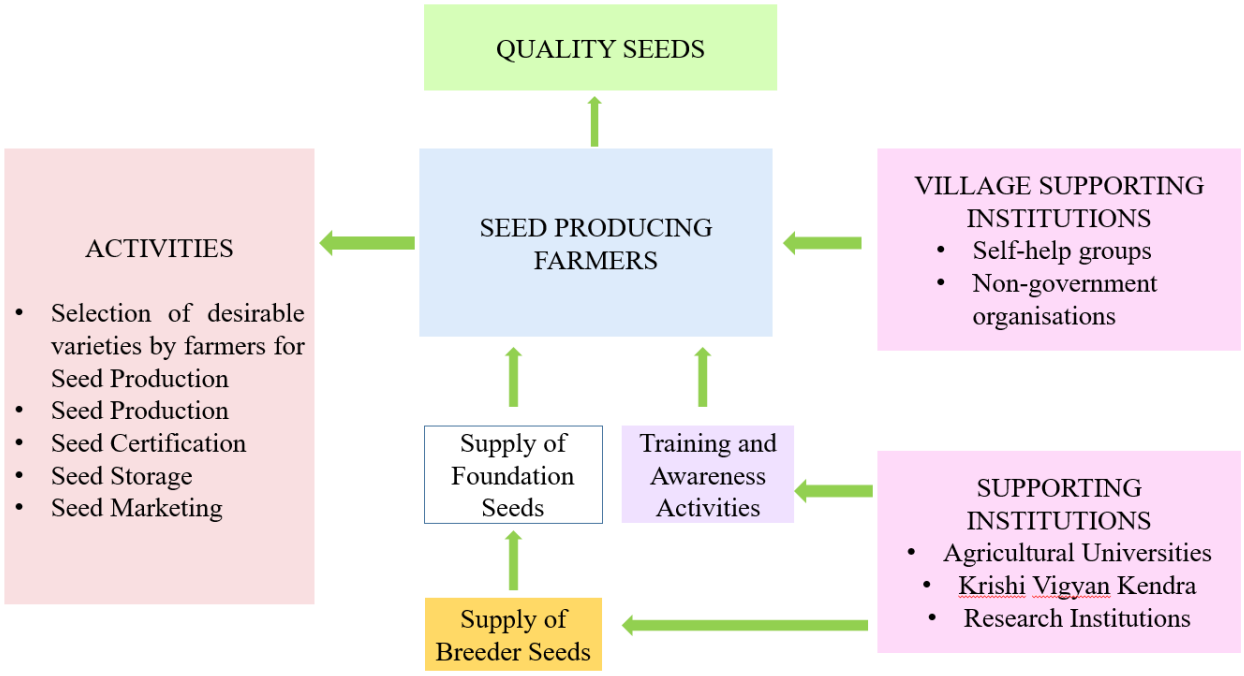

Fig.: Seed Village Programme Model

Goals of the Programme

a) Enhance production of certified/quality seeds at affordable rates
b) Increase profits of farmers
c) Boost Seed Replacement Rate in key crops (paddy, wheat, soybean, gram, etc.)
d) Ensuring the use of improved HYV seeds by all farmers in the villages
e) Ensure seed availability at the village level in various situations

Advantages of Seed Villages

1. **Enhanced Access to Quality Seeds:** SVP empowers farmers to produce quality seeds locally, reducing their dependency on external seed suppliers.
2. **Improved Agricultural Productivity:** Farmers using high-quality seeds produced under SVP often experience higher yields and better resistance to pests and diseases.
3. **Strengthened Informal Seed Systems:** The programme promotes seed exchange and sales within villages and neighbouring areas, creating a robust informal market.
4. **Skill Development and Capacity Building:** Through structured training sessions, SVP enhances farmers' knowledge of seed production, handling, and storage.
5. **Economic and Social Empowerment:** The program helps form Farmer Producer Organizations (FPOs) or Farmer Groups, which enable collective marketing, access to better resources, and negotiation power.

Challenges in Implementation

Despite the establishment of the SVP by the Indian government decades ago under various initiatives and experimental programs across three states, other states have yet to embrace the scheme efficiently (MoA&FW, 2018). The major challenges in SVP include:

1. **Availability of Foundation Seeds:** In many cases, certified seeds are distributed instead of foundation seeds, leading to the deterioration of seed quality and yield levels in later years.
2. **Seed Marketing:** It is a huge challenge for individual farmers to market the seeds they produce and secure a place in the highly competitive seed market without any institutional support.
3. **Farmers-produced seeds fall short of certification standards:** Many farmers struggle to meet the quality standards required for seed certification, which can become a barrier to entering the competitive seed market.
4. **Capacity:** Knowledge and skills related to quality seed production, storage, certification, conservation and marketing must be enhanced among the staff implementing SVP and also among farmers. This is found lacking in most of the cases.
5. **Value Chain Institution Coordination:** There is a need to promote coordination among a wide range of actors.

Case Study: The Seed Village Rajavaram's Journey to Agricultural Success (Bhuvana *et al*., 2023**)**

The Seed Village Programme emerged as a catalyst for change in the small village of Rajavaram in Telangana. Initially, the programme's focus was to train individual farmers to produce high-quality seeds. However, limited market access and inadequate storage facilities necessitated a new strategy. With the support of the National Bank for Agriculture and Rural Development (NABARD) and local agricultural officers, a group of farmers came together to form the **Rajavaram Farmer Producer Company (FPC)** in 2017. The FPC was established under the Mutually Aided Cooperative Societies Act, pooling resources and knowledge from ten founding members. The FPC received foundation seeds of the popular *Kunaram Sannalu* paddy variety and undertook seed production collectively. Their hard work paid off as the FPC established a trusted brand for quality seeds, which were sold locally under the "Rajavaram FPC" label. Eventually, their success attracted additional members, and the FPC expanded into other activities such as fertilizer stores, women's tailoring services, and pulse processing mills. Despite difficulties in securing constant supplies of foundation seeds, the FPC maintained its expansion *via* collaboration, frequent training, and clever marketing. Today, it exemplifies the power of collective action and the impact of empowering farmers through focused programs like SVP.

Conclusion

The Seed Village Programme (SVP) has demonstrated its potential to significantly enhance the yield of selected crop varieties compared to traditional landraces. However, fostering a collaborative network among research institutes, quality control agencies, agro-based NGOs, and community-based organizations is essential to enhance knowledge sharing and coordination in seed production and utilization. Where implemented effectively, the SVP has achieved remarkable outcomes, including improved crop productivity and a 65% increase in seed farmers' profitability within project areas. These advancements have reduced reliance on government-produced seeds, which are often hindered by delayed availability and high costs. By empowering farming communities and ensuring access to high-quality seeds, the SVP has emerged as a transformative initiative for enhancing agricultural productivity and securing the livelihoods of farmers.

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PRADHAN-MANTRI VAN DHAN VIKAS YOJANA

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ABSTRACT
The Pradhan Mantri Van Dhan Vikas Yojana (PMVDY) is a scheme launched by the Government of India to enhance the livelihood opportunities of tribal communities by empowering them to sustainably manage and add value to forest produce. The primary objective of the program is to promote the collection, processing, and marketing of non-timber forest products (NTFPs) through a decentralized approach. The scheme focuses on providing skill development, capacity building, and market linkage support to forest-based communities, thereby improving their income and overall socio-economic status. Under PMVDY, Tribal Cooperative Marketing Development Federation of India (TRIFED) works in partnership with state governments, ensuring that the tribal population benefits from the forest wealth and the value addition of forest produce. The program is expected to help achieve inclusive growth and socio-economic transformation, particularly in remote tribal areas.

Introduction
The Pradhan Mantri Van Dhan Yojana (PMVDY), also known as the Van Dhan Vikas Yojana (VDVY), is a program introduced by the Ministry of Tribal Affairs, Government of India, to enhance the livelihood opportunities of tribal communities. This initiative aims to develop value chains for forest-based products and boost tribal incomes through skill development and capacity-building programs. The scheme is a collaborative effort between the Ministry of Tribal Affairs and the Tribal Co-Operative Marketing Development Federation of India Limited (TRIFED). The scheme is overseen by the Ministry of Tribal Affairs as the Nodal Department at the central level, with TRIFED serving as the Nodal Agency at the national level. At the state level, the State Nodal Agency for Minor Forest Produce (MFPs) and district collectors play a crucial role in implementing the scheme at the grassroots level. Locally, the Kendras are managed by a Managing Committee, which is a Self-Help Group (SHG) comprising representatives from Van Dhan SHGs within the cluster. Launched on April 14, 2018, the scheme aims to enhance tribal incomes by adding value to forest-based products, thereby promoting sustainable livelihood opportunities for tribal communities through the utilization of forest resources (Van Dhan). The program seeks to leverage the traditional knowledge and skills of tribal communities by integrating technology and IT at various stages to enhance their expertise and transform their indigenous wisdom into sustainable economic ventures. The Van Dhan Vikas Yojana has the potential to significantly improve the lives of tribal populations by offering alternative livelihood opportunities and uplifting their socio-economic conditions. Beyond fostering entrepreneurship, the scheme also contributes to forest conservation and biodiversity protection. It encourages tribal communities to form clusters and engage in the processing of forest produce to enhance its value. These clusters are equipped with essential infrastructure, including tools and

equipment, along with training in value addition and entrepreneurship. The scheme also provides market linkages to the tribal communities for their products through various channels, including online platforms. The scheme has a three-tiered implementation process that involves the formation of Van Dhan Vikas Kendras at the village level, Van Dhan Vikas Sanrakshan Samitis at the cluster level, and Van Dhan Vikas Samuh at the district level. The scheme has a target of establishing 50,000 Van Dhan Vikas Kendras across the country, which will benefit around 10 lakh tribal entrepreneurs.

Key Highlights of Pradhan-mantri Van Dhan Vikas Yojana

At the unit level, the collection of forest produce will be carried out by Self-Help Groups (SHGs), each consisting of approximately 30 members, forming a Van Dhan Vikas 'Samuh.' These SHGs will also be responsible for the initial value addition of Minor Forest Produce (MFPs) using appropriate equipment such as small cutting and sieving tools, decorticators, dryers, and packaging tools, depending on the type of MFPs available in the region.

1. Aims to generate livelihood opportunities for tribal gatherers by empowering them to become entrepreneurs.
2. Focuses on establishing community-owned Van Dhan Vikas Kendras (VDVKs) in tribal-dominated forest districts.
3. Each Kendra will consist of 15 tribal Self-Help Groups (SHGs), with each SHG comprising up to 20 Non-Timber Forest Produce (NTFP) gatherers or artisans, benefiting around 300 individuals per Kendra.
4. Fully funded by the Central Government, with TRIFED allocating ₹15 lakh for every Van Dhan Kendra supporting 300 members.

Implementation of the scheme

Under the Van Dhan scheme, 10 Self-Help Groups (SHGs), each comprising 30 tribal gatherers, are formed to establish a Van Dhan Vikas Kendra. These Kendras serve as hubs for skill enhancement, capacity building, and setting up primary processing and value addition facilities. Tribal gatherers are trained and provided with working capital to process and enhance the value of forest products they collect. Under the guidance of the District Collector, these groups can market their products both within and beyond their respective states. TRIFED offers training and technical assistance to support this initiative. The scheme aims to establish 3,000 such Kendras across the country. Value addition is a key aspect of ensuring better prices for tribal communities. The scheme follows a three-stage value addition process, which plays a crucial role in boosting tribal incomes. At the grassroots level, procurement will be carried out by SHGs associated with implementing agencies. Additionally, the scheme will integrate and collaborate with other government programs, such as Ajeevika, to leverage existing SHGs. These SHGs will be trained in sustainable harvesting, primary processing, and value addition and will be organized into clusters to aggregate their stock in tradable quantities. The processed stock will then be supplied either to State Implementing Agencies or directly to corporate secondary processors. For further value addition at the district and state levels, the scheme will engage large corporations through a Public-Private Partnership (PPP) model. Under this model, private enterprises will handle processing and marketing, while the Central and State Governments will focus on infrastructure development and creating a conducive environment for scientific and systematic value addition. These large-scale processing hubs, managed by private entrepreneurs, will facilitate high-value product development. The Van Dhan Vikas Kendras will be a milestone in the economic empowerment of tribal communities by ensuring the efficient utilization of natural resources and fostering sustainable livelihoods in regions rich in Minor Forest Produce (MFPs).

Distribution of Fund

As per the guidelines, the total approved funding for a Self-Help Group (SHG) with 20 members is capped at ₹1 lakh. If a group has fewer than 20 members, the funding will be provided on a pro-rata basis. For instance, a 10-member SHG will receive ₹50,000, with a required working capital contribution of ₹10,000 from the group. The District Level Coordination and Monitoring Committee (DLCMC) and the State Nodal Department have the authority to approve the necessary procedures accordingly.

Facilities under Pradhan-mantri Van Dhan Vikas Yojna

1. Necessary infrastructure or building support will be set up in a beneficiary's house, a section of their home, or in government and gram panchayat buildings.
2. A tool kit will be provided, including essential equipment like small cutting and sieving tools, decorticators, dryers, and packaging tools, based on the available Minor Forest Produce (MFPs) in the region.
2) Fully equipped training facilities will be arranged for batches of 30 trainees, including raw materials for practical training and trainee kits containing items such as bags, notepads, pens, brochures, training manuals, and booklets.
3) Working capital for Self-Help Groups (SHGs) will be facilitated through partnerships with financial institutions, banks, and NSTFDC.
4) A Van Dhan Vikas Kendra will be formed by clustering 10 SHGs within the same village. If these groups operate successfully, common infrastructure facilities (such as permanent Kendras, warehouses, etc.) will be provided in the next phase for the benefit of all members.
5) The scheme covers a wide range of MFPs with value addition potential, including tamarind, mahua flower, mahua seed, hill broom, chironjee, honey, sal seed, sal leaves, bamboo split, myrobalan, dried mango (amchur), aonla (candy/churan), seed lac, tez patta, cardamom, black pepper, turmeric, dry ginger, cinnamon, coffee, tea, and sea buckthorn tea. Additionally, any other MFP with potential for value enhancement may also be included in the initiative.

Conclusion

Pradhan Mantri Van Dhan Vikas Yojana (PMVDVY) is a transformative initiative aimed at enhancing the livelihoods of tribal communities by promoting value addition to Minor Forest Produce (MFPs). By integrating traditional knowledge with modern technology, the scheme the empowers tribal gatherers to become entrepreneurs ensuring sustainable income generation and financial independence. Through the establishment of Van Dhan Vikas Kendras (VDVKs), the scheme provides training, infrastructure, and financial support, enabling tribal Self-Help Groups (SHGs) to process, package and market their products effectively. The initiative not only boosts rural employment but also contributes to forest conservation and biodiversity protection. With a vision to establish thousands of Kendras across India, the PMVDVY is a significant step toward socio-economic empowerment, self-reliance and sustainable development for tribal populations.

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ENHANCING CROP PROTECTION: ADVANCING PESTICIDE APPLICATION WITH EMERGING TECHNOLOGIES

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Abstract
Applying pesticides correctly is crucial to agricultural pest management since it protects crops and increases productivity. In order to achieve effective pesticide dispersion, minimise waste, and lessen the impact on the environment, the choice of spraying equipment is essential. The frequency of application, the availability of diluents (such as water, oil, or kerosene), the size and features of the treatment area, labour resources, and other considerations all have a role in the choice of spraying equipment. Other factors that influence decision-making include the equipment's cost, longevity, operational effectiveness, and post-purchase maintenance. The efficiency of pest control measures is determined by the methods used for applying pesticides as well as the choice of equipment. The impact of the chemical is maximised when spray droplets are applied uniformly to the target areas using the right application techniques. Since pesticides are applied in different concentrations, diluents are frequently needed to ensure uniform dispersion. The most widely utilised carrier is water, whose volume needs to be changed based on the application technique. It is essential to understand these factors in order to improve crop health, increase pesticide efficiency, and guarantee sustainable farming methods.

Keywords: Agricultural Chemicals, Application Techniques, Crop Protection, Pesticide Application, Spraying Equipment

Introduction

Pesticide application is a crucial component of modern agriculture, playing a vital role in pest and disease control while enhancing crop productivity. Among the various application techniques, spraying remains the most commonly used method, encompassing hydraulic, backpack, basal trunk, and aerial spraying. The selection of an appropriate method depends on factors such as pest behaviour, target site characteristics, and pesticide properties (Tudi *et al*., 2022). Proper spraying ensures effective adhesion and retention on target surfaces, leading to improved distribution and efficacy. Advancements in pesticide application technology have led to the development of precision-based methods that enhance efficiency while reducing environmental impact. Unmanned Aerial Vehicles (UAVs) and Mister Sprayers improve pesticide availability and control efficacy, enabling targeted application and minimizing drift (Xiao *et al*., 2020). Additionally, Controlled-Release Systems, such as photothermal controlled-release microcapsules, enhance pesticide utilization by providing on-demand delivery and reducing environmental residues (Huang & Jiang, 2024). Electrostatically Charged Sprays further improve deposition efficiency by reducing spray volumes and optimizing droplet size, though their adoption remains limited. The effectiveness of pesticide application is influenced by droplet size, distribution, and environmental factors such as

wind speed, nozzle height, and plant growth stage (Xiao *et al*., 2020). However, despite technological advancements, improper pesticide use poses significant health and environmental risks. Ensuring proper application techniques, adopting advanced equipment, and enforcing Integrated Pest Management (IPM) policies can help mitigate these risks and promote sustainable pesticide use (Tudi *et al*., 2022).

Recent trends in insecticide application

Technologies that focus on improving efficiency, safety, and environmental sustainability are advancing rapidly. These advancements are driven by the need to optimize pesticide use, reduce environmental impact, and enhance the precision of pest control.

Electrostatic and Controlled Droplet Application: New nozzle designs and electrostatically charged sprays improve droplet control, enhancing deposition on target areas and reducing drift (Wang *et al*., 2021). Electrostatic spraying charges spray droplets, increasing their attraction to plant surfaces and improving coverage. Using an electrostatic-induction nozzle, this method ensures deeper canopy penetration and greater efficiency than conventional techniques (Zhao *et al*., 2024). Controlled Droplet Application (CDA) further optimizes spray efficiency by producing uniform droplet sizes through specific nozzle types and pressure adjustments, ensuring consistent coverage with minimal drift. When combined with electrostatic charging, these techniques significantly enhance pesticide application precision. Electrostatic spraying increases droplet deposition efficiency by two- to seven-fold, improving insect control even at reduced pesticide rates (Zhao *et al*., 2024). Research continues to refine charge-to-mass ratios and develop UAV-based systems for better coverage (Lin *et al*., 2023). Advanced technologies and improved application techniques can contribute to more sustainable pest management in agriculture.

Micro and Nanotechnology: These technologies are being integrated into pest management to enable controlled release and targeted delivery of agrochemicals, reducing the amount of pesticide needed and enhancing efficacy (Khandelwal *et al*., 2016; Sujayanand *et al*., 2021). Nanoparticles and nanocomposites are used for the detection, degradation, and removal of pesticides, offering a more environmentally friendly approach.

Biodegradable and Natural Formulations: There is a growing interest in using biodegradable materials and natural insecticides, such as essential oils and plant-based compounds, as alternatives to synthetic chemicals. These are particularly appealing for organic food production and as affordable solutions in developing countries (López *et al*., 2005; Stejskal *et al*., 2023). Nano-based formulations increase the bioavailability of pesticides, ensuring that a higher proportion of the active ingredients reach the target pests. This improvement in delivery efficiency contributes to enhanced pest control outcomes (Stejskal *et al*., 2023).

Closed Systems and Safety Enhancements: The introduction of closed systems for transferring pesticides reduces operator exposure and contamination risks. These systems are often combined with microprocessor-controlled equipment for more precise application (Li *et al*., 2021; Xiong *et al*., 2024).

Drones and Robotics: Even in difficult-to-reach locations, drones and robotics in agriculture allow for precision monitoring and targeted pesticide application, lowering chemical use and increasing the effectiveness of pest management (Sujayanand *et al*., 2021). Drones with sophisticated imaging capabilities can identify early infestation indicators, enabling farmers to take action before

significant crop losses happen. Drones provide for focused spraying as opposed to broad application by mapping impacted areas in real time. Drones that spray reduce the impact on the environment by applying pesticides only where necessary. Farmers who manually apply pesticides run a significant risk of exposure to dangerous chemicals. Robotic systems and autonomous drones offer a safer substitute by removing direct human contact with pesticides and swiftly and precisely covering wide areas, increasing the effectiveness and sustainability of pest management (Sujayanand *et al*., 2021).

Pesticide application techniques

The methods used to apply agricultural chemicals to crops, weeds, or soil are collectively known as application techniques. These techniques play a crucial role in ensuring effective pest control, with appropriate dosage and even distribution of spray droplets being essential for maximizing efficacy. To achieve uniform coverage, carriers or diluents are mixed with pesticides, with water being the most commonly used diluent. The volume of water required as a carrier depends on the specific application method and the target area. A variety of spraying equipment is available to accommodate different application needs. Hand-operated hydraulic sprayers, such as knapsack sprayers, are commonly used for small-scale applications, while power-operated hydraulic sprayers, including tractor-mounted sprayers, are preferred for larger agricultural areas. Air carrier sprayers (mist blowers) utilize air currents to distribute chemicals effectively, while electrostatic sprayers (electrodyne sprayers) enhance droplet adhesion to plant surfaces, improving coverage and reducing chemical waste. Other specialized equipment includes Birky knapsack sprayers, controlled-droplet application (CDA) sprayers, and dusters, each designed for specific pesticide formulations and application requirements.

Conclusion

Applying pesticides effectively is essential to safeguarding crops while lowering hazards to the environment and human health. Precision has increased thanks to innovations like controlled-release systems, UAVs, and electrostatic sprays, but problems like chemical residues and pesticide drift still persist. In the future, smart spraying technologies, environmentally suitable substitutes, improved safety protocols, and more stringent restrictions should be the main priorities. In order to ensure long-term productivity and safety for farmers and consumers, agriculture may evolve towards a future with healthier crops, higher yields, and less environmental harm by combining innovation, sustainable methods, and responsible pesticide usage.

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UNSEEN, UNHEARD, UNHEALTHY: THE TRUTH ABOUT PESTICIDE RESIDUES IN AGRICULTURE

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Abstract

Pesticides are widely used in agriculture to protect crops from various pests, diseases, and weeds, playing a key role in ensuring food security. However, the presence of pesticide residues on food after harvest has become a growing concern due to their potential health risks. This article provides the sources and persistence of pesticide residues, their health implications, and their environmental impact. It discusses key pesticide types and their mechanisms of action. The article also reviews several pesticide-related incidents in India, such as the Endosulfan tragedy in Kerala and contamination cases in other states like Punjab and Uttarakhand. Additionally, it gives the existing regulatory frameworks, such as the Insecticides Act and the Food Safety and Standards Act, and explores current efforts to mitigate the risks associated with pesticide residues. The paper concludes by sustainable agricultural practices, improved enforcement of pesticide regulations, and greater public awareness to reduce the risks of pesticide residues and ensure safer food production.

Introduction

Pesticides are widely used in agriculture to protect crops from pests, diseases, and weeds, ensuring food security and high yields. However, while these chemicals play a crucial role in modern farming, they come with a hidden risk: pesticide residues. These chemical remnants can persist on crops even after harvesting and processing, making their way into the food supply and, ultimately, onto our plates (WHO, 2020). Pesticide residues, defined as the trace amounts of pesticides that remain on or in food after application, have become a growing concern worldwide due to their potential health and environmental impacts. While many countries regulate the permissible limits of these residues, concerns remain about the long-term consequences of consuming food contaminated with pesticides, particularly when they exceed safety thresholds (EPA, 2021).The consequences of pesticide residue exposure can be severe, ranging from acute health effects like skin irritation and nausea to chronic conditions such as cancer, neurological damage, and reproductive problems (FSSAI, 2020).In addition to the direct impact on human health, pesticide residues also pose significant environmental risks. The persistence of these chemicals in the soil and water can harm ecosystems, reducing biodiversity and polluting natural resources (FAO, 2019). Over dependence on chemical pesticides has also contributed to the rise of pesticide resistant pests, further complicating efforts to manage agricultural practices sustainably (Codex Alimentarius, 2020). This article deals with the science behind pesticide residues, their impacts on human health and the environment,

the policies governing pesticide use, and potential solutions for reducing their presence in our food supply.

What Are Pesticide Residues?

Pesticide residues are the leftover traces of chemicals used to control pests during food production, storage, and transport. These residues may include the pesticide itself, its breakdown products, or by products that still pose a potential health risk. Though pesticides are used to protect crops from insects, fungi, and weeds, residues that remain in food or on the environment can be harmful to human health and the ecosystem.

The Science Behind Pesticides and How it Works

Pesticides work through various mechanisms, depending on their type and purpose.

1. **Insecticides:** These chemicals are designed to kill or repel insects that harm crops. Insecticides like organophosphates (e.g., chlorpyrifos) interfere with the nervous system of insects, ultimately killing them. Organophosphates block acetylcholinesterase, an enzyme essential for proper nerve function in both insects and humans.
2. **Herbicides:** These are chemicals that target weeds that compete with crops for nutrients and water. Glyphosate, one of the most widely used herbicides, works by inhibiting a specific enzyme pathway in plants that is essential for their growth. This kills the plant by preventing it from synthesizing essential amino acids.
3. **Fungicides:** These chemicals control fungal growth that can infect crops and reduce yield. Fungicides like mancozeb or carbendazim work by disrupting cellular processes in fungi, preventing their reproduction and growth.
4. **Rodenticides:** Used to control rodent populations that can damage crops, rodenticides like bromadialone act by interfering with the blood clotting process in rodents, leading to internal bleeding and death.

Even though they are effective, the use of these chemicals often results in residues remaining on the crops. These residues can potentially be harmful to humans and animals who consume the contaminated food.

Key Factors Contributing to Pesticide Residue Issues

1. **Improper Application:** Incorrect dosage, timing, or application methods can lead to excessive pesticide residues.
2. **Persistence of Pesticides:** Some pesticides are designed to linger in the environment, leading to long-term toxicity in both the soil and food products.
3. **Lack of Regulation and Monitoring:** Without strong regulations and monitoring systems, pesticide use can be out of control, leaving high levels of harmful chemicals in the environment and food.

Persistence and Bioaccumulation

Some pesticides persist in the environment for months or even years after application. For example, certain organophosphates and organochlorines have been shown to remain in the soil, groundwater, and air, continuously posing a risk to both wildlife and humans. Pesticides can also bioaccumulate, meaning they build up in the food chain. For instance, if pesticide residues are present in crops consumed by herbivores (e.g., cows or goats), the chemicals can accumulate in the animal's tissues. When humans consume animal products like meat, milk, or eggs, the pesticide residues are passed

along. This bioaccumulation effect is especially concerning for persistent pesticides, which don't break down quickly and can accumulate to harmful levels.

Chemical Breakdown of Pesticides

After pesticides are applied, they undergo chemical degradation, either through natural processes like photodegradation (breakdown by sunlight), hydrolysis (breakdown by water), or microbial activity. The breakdown products, often called metabolites, may still be toxic or harmful, and they can also remain in the environment or in food crops. For example, the breakdown of chlorpyrifos (an organophosphate insecticide) results in toxic metabolites, which can contribute to the harmful effects on human health, even if the parent pesticide is not present in significant amounts.

Health Impact of Pesticide Residues

Acute Health Effects

Immediate exposure to high levels of pesticide residues can cause acute poisoning. Symptoms include skin rashes, irritation, nausea, dizziness, and breathing difficulties. In extreme cases, pesticide poisoning can result in convulsions, coma, and even death. People working in agricultural fields or those living near areas where pesticides are heavily used are at the highest risks.

Chronic Health Effects

Chronic exposure to low levels of pesticide residues over long periods can lead to severe health conditions such as:

- **Cancer:** Several pesticides, like organophosphates, have been linked to cancers of the brain, liver, and prostate.
- **Reproductive Harm:** Pesticides can interfere with reproductive health, leading to birth defects, infertility, and other reproductive issues.
- **Neurological Damage:** Pesticides can affect the brain and nervous system, leading to cognitive decline, memory issues, and even Parkinson's disease.
- **Endocrine Disruption:** Some pesticides mimic or block hormones, leading to endocrine disruption, which can cause developmental and health problems.

Vulnerability of Children

Children are particularly susceptible to pesticide exposure due to their smaller size, developing organs, and higher intake of food and water. Exposure to pesticides during critical developmental stages can lead to long-term health issues, including cognitive deficits, behavioral problems, and developmental disorders.

Pesticide Residue Incidents in India

India has witnessed several significant pesticide-related accidents over the years, often due to overuse or misuse of pesticides in agriculture. with significant cases in states like Kerala, Punjab, Uttarakhand, and Madhya Pradesh. In Kerala, the Endosulfan crisis (2000s) caused severe health issues, leading to a nationwide ban. In 2016, pesticide residues in fruits and vegetables were found to exceed safe limits, prompting regulatory action. Punjab saw pesticide contamination in staple crops like rice and wheat in 2015, while Uttarakhand faced pesticide residues in apples in 2017. Madhya Pradesh's cotton industry also struggled with pesticide misuse in 2019. In response, the government has strengthened regulations, promoted organic farming, and conducted farmer training programs to ensure safer pesticide practices. In 2008, the Haryana pesticide poisoning incident made headlines. Farmers in the state used illegal or unapproved pesticides on their crops, leading to food contamination and poisoning. This highlighted the need for more stringent pesticide regulation.

Policies and Regulations on Pesticides in India

India, being one of the largest producers and consumers of pesticides, it has established several policies to regulate pesticide use and ensure that pesticide residues in food remain within safe limits.

1. The Insecticides Act, 1968

The Insecticides Act of 1968 is the primary legislation that governs the registration, distribution, sale, and use of pesticides in India. The Act aims to control the import, manufacture, sale, transport, distribution, and use of insecticides to prevent risks to human health and the environment. Key provisions include:

- **Registration of Pesticides:** Before any pesticide can be marketed or used in India, it must be registered with the Central Insecticides Board and Registration Committee (CIBRC). This committee evaluates the safety, efficacy, and toxicity of pesticides before they are approved.
- **Safety Standards:** The Act sets safety standards for the application and storage of pesticides to minimize risks to human health and the environment.

2. The Food Safety and Standards Act, 2006 (FSSA)

The Food Safety and Standards Authority of India (FSSAI), established under the Food Safety and Standards Act of 2006, is responsible for ensuring that food products meet the safety standards. The FSSAI sets Maximum Residue Limits (MRLs) for pesticides in food items, establishing safe levels of pesticide residues that should not be exceeded in food products.

3. The Pesticide Management Bill (Draft)

In 2020, the Indian government introduced the Pesticide Management Bill (Draft), aimed at improving the management of pesticide use in the country.

- **Banning of Harmful Pesticides:** The bill proposes to phase out the use of certain harmful pesticides and encourage the use of alternatives that are less toxic.
- **Stronger Monitoring:** The bill strengthens the framework for monitoring pesticide residues in food and ensures more effective enforcement.
- **Awareness Programs:** The bill includes provisions for educating farmers on the safe use of pesticides, Integrated Pest Management (IPM), and alternatives to chemical pesticides.

While the bill has not yet become law, its draft represents a critical step towards improving pesticide management in India.

4. State-level Policies and Guidelines

Several Indian states have adopted their own regulations concerning pesticide use and pesticide residue testing. For example, states like Punjab, Haryana, and Uttar Pradesh, which are major agricultural producers, have developed their own monitoring systems for pesticide residues. These state-level measures often focus on the enforcement of MRLs and the registration of pesticides for use in agriculture. Additionally, India has introduced the National Pesticide Residue Monitoring Program (NPRMP), which monitors pesticide residues in food products both domestically produced and imported into the country. The program is intended to ensure compliance with the FSSAI's MRLs and prevent the entry of food products with excessive pesticide residues into the market.

Challenges in Enforcement

Despite these laws, there are significant challenges in enforcing pesticide regulations in India:

- Lack of Awareness Among Farmers: Many small-scale farmers are unaware of the safe pesticide application practices. This often results in overuse or misuse of pesticides.

- Improper Application: Farmers may apply pesticides at inappropriate times or in excessive amounts, leading to higher residue levels in food.
- Weak Monitoring and Inspection: especially in rural areas, Many local markets lack testing facilities to check pesticide levels in food, leading to potential risks for consumers.

International Standards and Trade Implications

India's pesticide residue standards align with international organizations such as the Codex Alimentarius Commission, which sets global guidelines for food safety. However, discrepancies between local pesticide use practices and international standards have led to trade challenges, as some countries may restrict or ban imports of Indian agricultural products if pesticide residues exceed permissible limits. This has highlighted the importance of improving pesticide residue management to enhance India's agricultural exports.

Global Regulatory Standards on Pesticide Residue

Countries around the world have established regulatory standards for pesticide residues, setting Maximum Residue Limits (MRLs) to ensure food safety. Agencies like the U.S. Environmental Protection Agency (EPA) and the European Food Safety Authority (EFSA) regularly review and update these limits. However, regulatory frameworks vary from country to country, and enforcement of these standards can be inconsistent, especially in developing countries like India.

How Can We Reduce Pesticide Use?

To mitigate this, we should not completely rely only on chemical pesticides and we have to explore some safer alternatives like,

1. **Integrated Pest Management (IPM):** This holistic approach combines biological controls, cultural practices, and minimal pesticide use. IPM ensures that pesticides are only used when absolutely necessary, significantly reducing pesticide reliance.
2. **Supporting Sustainable Farming Practices:** Moving toward organic farming, agroecology, IFS and precision farming can reduce pesticide use. These farming methods emphasize sustainability and use fewer chemicals.
3. **Investing in Research:** Research into biological pesticides and other pest control methods can provide safer alternatives to traditional chemical pesticides. Governments and industries should prioritize this research and facilitate the regulatory approval of new, less toxic pesticides.
4. **Better Monitoring and Regulation:** Governments must improve pesticide monitoring in both food and the environment. This will help ensure that residue levels remain within safe limits and protect consumers.
5. **Biopesticides:** Biopesticides, derived from natural materials like plants, bacteria, and minerals, offer an alternative to synthetic pesticides. These products are less toxic and more environmentally friendly, making them an increasingly popular choice.

Good Agricultural Practices (GAP) and Safe Use of Pesticides

What is GAP?

GAP focuses on safe pesticide application techniques, appropriate timing, and using the correct dosage. It also includes guidelines on crop rotation, the use of protective wear for workers, and pest management strategies that prioritize alternatives to chemical pesticides. GAP involves applying pesticides in a manner that minimizes their impact on human health, the environment, and non-target organisms. By implementing GAP, farmers can reduce the amount of pesticide residue left on food, making it safer for consumers.

Practical Steps for Reducing Exposure to Pesticide Residues

As consumers, there are several actions we can take to reduce our exposure to pesticide residues:

- Wash Produce Thoroughly: Washing fruits and vegetables under running water can help remove pesticide residues. Dry produce with a clean cloth towel or paper towel when possible.
- Peel and Trim: Peel fruits and vegetables when possible, and trim fat from meat to reduce pesticide accumulation. Discard the outer layer of leafy vegetables, such as lettuce or cabbage
- Buy Organic: Organic foods typically have lower pesticide levels and are a safer choice for consumers.
- Support Sustainable Farming: Supporting local farmers who use sustainable practices can encourage broader changes in agricultural methods.

Conclusion

Pesticide residues play a significant challenge to both human health and the environment. While pesticides are indispensable in modern agriculture, their overuse and misuse can result in harmful chemical residues that pose serious risks to consumers and ecosystems. In India, multiple pesticide-related incidents have underscored the need for stricter regulations, more effective enforcement, and widespread adoption of sustainable agricultural practices. The government has made strides through policies such as the Insecticides Act and the Food Safety and Standards Act, but challenges in enforcement, particularly in rural areas, persist. Moving forward, a shift toward Integrated Pest Management (IPM), organic farming, and the use of biopesticides can help mitigate pesticide dependence and its associated risks. Public health must be prioritized by promoting safer alternatives, educating farmers, and encouraging consumer choices that reduce pesticide exposure. By taking collective action, we can create a healthier agricultural system that protects both people and the environment for future generations.

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PRODUCTION OF HEALTHY CHILLI SEEDLINGS THROUGH ECO-FRIENDLY APPROACH IN WEST BENGAL

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Introduction

Chilli is one of the most common growing vegetable cum spice in every Indian cuisine and is grown throughout the country. The pungent types are used as green chilli, whole dry chilli, chilli powder, chilli paste, chilli sauce, chilli oleoresin or as mixed curry power. It is well adapted crop to different agro-climatic regions of India and can be grown throughout the year. Farmers of West Bengal grow chilli in highly diverse agro-climatic region from Hilly and Terai soils of Himalayan foot hills in the North, Red lateritic and gravelly soils in the West, and coastal saline soils in the South to rich alluvial soils in the Central region. It is mostly grown as annual crop but some perennial types are also available. Chilli is a transplanted crop and it is very difficult to raise healthy seedling by the farmers as the seedlings are affected by erratic rainfall, disease like damping off and virus. Therefore, precaution should be taken to raise healthy seedling for better establishment in main field without using harmful chemicals for environmental sustainability.

Important varieties

Open pollinated varieties

Pusa Sadabahar

The fruits are borne in cluster, upright with 5-8 fruits per cluster. The average potential yield is 8-10 t per ha. The plants are perennial in nature i.e. it can be kept in the same field for 2-3 years, however, the yield gets reduced.

Pusa Jwala

The plants are dwarf and bushy. Fruits are 9-10 cm long, curved, thin, light green coloured and medium pungent. The average yield is 7.5 t per ha of green chilli. The variety is tolerant to mosaic.

Bidhan Chilli 4

Fruits are green and bright red in colour when ripe with pointed fruit at blossom end. It can be used as dual purpose (green and dry chilli) variety and have field resistance against pepper leaf curl virus and fruit rot diseases. The average green fruit yield is 104 q per ha and dry yield is 22 q per ha.

Kashi Gaurav

The plants are bushy, fruits are dark green and turn dark red when ripe. Fruits are 9-11 cm long and 1.1-1.2 cm thick, pendant and pungent. Average red ripe fruit yield 150 q per ha. Tolerant to anthracnose, thrips and mites.

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Hybrids

Arka Swetha

Fruits are light green, turns red when ripe, the average fresh fruit yield is 38 t per ha and dry yield is 6 t per ha.

Seedling raising

Nursery Bed Preparation

Chilli seeds are sown on raised nursery bed. As it is sown from July to August, the nursery bed should be prepared under protected condition. Low cost polytunnel or insect proof net house is best for raising seedlings. Before bed preparation, ploughing is done properly and kept land for sun drying or solarization. Application of *Trichoderma viride* with cow dung manure (@ 1 kg per 5 kg cow dung manure) at least 15 days before sowing is beneficial. Raised nursery beds of 1 m width with convenient length and 10-15 cm in height are prepared. An about 50-60 cm distance is kept between two beds to carry out different operations like watering, weeding and hoeing etc.

Seed rate

Open pollinated Varieties: 500 g per ha
Hybrids: 250 g per ha

Seed treatment

Seeds can be treated with *Trichoderma viride* bio fungicide (@10 g per kg seed) or *Pseudomonas fluorescens* (@ 10 g per kg seed) to avoid damage from damping-off and other diseases.

Raising of Seedlings

The seeds are sown in line at a spacing of 5-7 cm distance between lines and at a depth of 2-3 cm. After sowing, lines are covered with a fine layer of soil. The beds should be covered with straw or dry grass and light watering is done by rose can. The watering should be done in morning and evening or as per the need till germination is completed. The seeds germinate within 6-7 days after sowing and immediately after germination dry straw or grass is removed. After germination regular watering should be done to keep the seedling healthy.

After germination care

Hoeing should be done by sharpen bamboo stick to make soil loose and proper aeration in soil. Hand weeding should be done to keep the nursery weed free. Application of *Trichoderma viride* or *Pseudomonas fluorescens* @ 5g per litre water is also beneficial. Installation of yellow sticky trap to catch various sucking pest like whitefly is helpful. Water stagnation should be avoided. Uncovering of polytunnel during sunny day should be done for early growth of the seedlings. Spraying of Neem Seed Kernel Extract @ 5 % at 10 days after germination is beneficial to manage chewing pest.

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Seedlings for transplanting

One month old healthy seedlings are ready for transplanting when they attain a height of 12-15 cm with 2-3 true leaves. Before transplanting, seedlings are hardened by withholding water one week before transplanting.

Management of nursery disease and pest

Damping off

The disease symptom appears as rotting before emerging from the soil. After germination, seedlings develop water soaked lesions at the base of stem. The infected region turns brown or black. In severe stage, plants shrivel and topple over. Covering the nursery soil after cultivation followed by sun drying will reduce the inoculums of pathogen. Avoid shade places for nursery establishment, avoid flood irrigation and maintain optimum moisture level in nursery. Before sowing, seeds should be treated with *Trichoderma viride* bio fungicide (@10 g per kg seed) or *Pseudomonas fluorescens* (@ 10 g per kg seed).

Leaf curl disease

In the young seedlings, the upper leaves curl towards midrib and become deformed. The growth of the seedlings stopped. It is a viral disease and transmitted by whitefly. Setting of yellow sticky trap @ 1 trap per 10 nursery bed (3 m × 1 m) is effective. Application of nicotine dust powder @ 100 gm per sq. meter area is also found to be effective in controlling whitefly.

Mite

The symptom appears as downward curling and crinkling of leaves with elongated petiole. The growth of seedlings is stunted. Spraying of neem oil @ 5 ml per litre of water at 10 days interval is found to be effective to control mite.

Conclusion

By following above technology, the healthy and disease free seedlings can be produced. Besides, the disease and pest infestation will be very less in main filed. Transplanting of healthy seedling will enhance crop growth and yield.

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NANOBUBBLE TECHNOLOGY

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Introduction

Nano Bubble Technology (NBT) is a revolutionary innovation that produces bubbles with diameters smaller than 100 nanometers. These microscopic bubbles possess unique physical and chemical properties, making them highly suitable for various applications, including aquaculture, agriculture and water treatment. NBT has been shown to effectively improve water quality by removing pollutants, increasing dissolved oxygen levels, and enhancing microbial activity. Bubbles similar to coronavirus.They have strong negative charge that keeps them stable in liquid and enables them to continuously participate in and stimulate physical, biological and chemical interactions. They are neutrally buoyant and can remain suspended in liquid for weeks without rising to the surface.The oxygen dissolving efficiency in the nanobubble is 85 percent, which is significantly higher than that of conventional aeration by over three times

Unique characteristics

- **Longevity and Stability :** Nanobubbles are highly stable and can last for months without bursting.It allows them to remain suspended in water for periods ranging from a few hours to several months.
- **High Surface Charge :** NBT carry a negative charge, especially in neutral to basic pH, which helps them attract pollutants, making them useful for water treatment.
- **Implications of Internal Pressure :** The high internal pressure caused by their small radius makes NBs particularly reactive, especially when they collapse, which can generate free radicals that destroy organic contaminants.
- **Implications of Internal Pressure :** NBT have high surface area-to-volume ratios and do not easily rise to the surface of the liquid, remaining suspended and effectively interacting with contaminants.

Mechanism of Nanobubble Technology in Aquaculture

- **Oxygen Concentrator :** When air gets sucked into the system, the oxygen concentrator absorbs nitrogen and other gases present in the air and increases the concentration of oxygen and produces pure oxygen
- **Ozone Generator :** Oxygen concentrated from the air was fed into ozone generator at a flow of 1 L/min.
- **Nanobubble Generator :** The generated ozone was then diffused with water inside the nanobubble generator to form NBO_3 and returned to the tank. It has small pores such that when air and water are fed into it, water nanobubbles pop out.

Generation of Nanobubbles Methods

- **Cavitation :** Cavitation is a mechanical process that creates nanobubbles by exploiting changes in pressure within a liquid.Liquid is forced through a constriction, such as a nozzle

or orifice, causing a rapid drop in pressure. This leads to gas being dissolved into the liquid and forming bubbles upon pressure recovery.This water initially appears milky white in colour and contains microbubbles. But when left undisturbed for 10 minutes, it becomes transparent containing only nanobubbles. high DO level: 25-30 ppm will be ensured.

- **Electrolysis :** Electrolysis uses electrical energy to split water molecules and generate nanobubbles of specific gases, such as hydrogen or oxygen.When an electric current is passed through water, gas molecules are released at the electrodes (anode and cathode), forming nanobubbles directly in the liquid.It allows water with gas bubbles to circulate and cause bubbles to break into smaller sizes.Allows controlled production of specific gases and does not require external gas supply.
- **Nano-pore membrane :** Nano-pore membrane technology uses specialized membranes to create nanobubbles by forcing gas through extremely small pores.Gas is pressurized and passed through a membrane with nanopores, ensuring the formation of nanobubbles as the gas diffuses into the liquid.It allows water with gas bubbles to circulate and cause bubbles to break into smaller sizes.Allows controlled production of specific gases and does not require external gas supply.To achieve smaller bubble, a higher pressure with smaller gas flow rate.

Suitable systems for Nanobubble Technology

- ❑ Hatchery
- ❑ Recirculation aquaculture system (RAS)
- ❑ Indoor systems
- ❑ Ponds (e.g. adding NBs-water into culture pond)

Types of Nanobubbles

Air Nanobubbles : Air nanobubbles are formed using regular atmospheric air. Enhances dissolved oxygen levels in water, promoting aquatic life in aquaculture and wastewater treatment. Ideal for non-reactive applications where chemical use is minimal.

Oxygen Nanobubbles : Oxygen nanobubbles are generated by infusing oxygen gas and are known for their high oxidative potential. Promotes the breakdown of organic matter. Boosts oxygen levels in aquaculture systems, reducing fish stress and improving growth.

Ozone Nanobubbles : Ozone nanobubbles contain ozone gas and are particularly effective due to their strong oxidative and disinfectant properties.Kills bacteria, viruses, and other pathogens. Breaks down persistent organic pollutants in wastewater treatment systems.

Conclusion

NBT is a promising technology, and its application has spread significantly over the last decade to a wider range of sectors covering energy, environment, industry, agriculture, and aquaculture.

Improve fish immunity

- ❖ Turn on an array of innate immune genes.
- ❖ Respond more effective to bacterial infection.
- ❖ Relatively safe for fish and shrimp
- ❖ Improve efficacy of vaccine.

Reduce pathogen loads

- ❖ Bacteria, Virus 96.11-97.92 % after 10 min treatment.

Improve water quality

- ❖ Improve DO
- ❖ Reduce organic loads
- ❖ Reduce toxic gases

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THE ROYAL TREE: SANDALWOOD (*Santalum album*)

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Abstract
In Indian culture, sandalwood (*Santalum album L.)* is a valuable tree. It is the second most expensive plant in the world. The sandalwood tree is often referred to as the "royal tree" due to its high value and significance in various cultures. Its heartwood produces sandalwood oil, which is prized for its fragrance and therapeutic properties. Historically, sandalwood has been associated with royalty and luxury, used in religious rituals, perfumes, and traditional medicine. Additionally, its slow growth and limited supply contribute to its esteemed status, making it a symbol of wealth and prestige. Although the species is semiparasitic and has the ability to photosynthesize, it is dependent on the host plant for organic matter, water, and mineral sustenance. Indian tradition dictates the use of sandalwood from the newborn till the cremation. Sandalols are the aromatic components of sandalwood oils. The Indian market places a high commercial value on sandalwood trees and oil.

Keywords: Heartwood, Semiparasitic, Sandalols, Therapeutic.

Fig. 1 Sandal Wood

Introduction

Santalum album, a small to medium-sized evergreen tree, is native to India and found in various regions, including Karnataka, Tamil Nadu, and other states. It has a smooth, reddish-brown bark, thin leaves, and straw-colored flowers. The tree is a root parasite, associating with various host plants, and requires specific climate, topography, and soil conditions to thrive. Sandalwood is highly valued for its fragrant heartwood, used for carving, oil extraction, and medicinal purposes. The tree's natural regeneration occurs through seeds and root suckers, with seedlings requiring lateral shade and being sensitive to drought and waterlogging. Artificial regeneration methods include seed sowing, transplanting, and vegetative propagation, but can be challenging due to the tree's parasitic nature and sensitivity to root disturbance. Sandalwood is susceptible to spike disease, caused by a virus transmitted by Lantana, which can impact its growth. The tree's wood is highly prized for its

fragrance, durability, and medicinal properties, with the heartwood being used for carving, oil extraction, and traditional medicine**.**

Morphology of sandalwood: Small to medium size, evergreen, glabrous tree with slender drooping branchlets. Generally, attains a height of 13.5-16.5 m and 1-1.5 m girth. Bark reddish-brown or dark brown, smooth in young trees and rough with deep vertical cracks in old trees. Leaves are thin, opposite, ovate or ovate-lanceolate, blade entire, 3.8 to 6.4 cm. Flowers are straw-colored, brownish-purple or violet, unscented in axillary or terminal panicled cymes. The ovary is unilocular and semi-inferior. The tree begins to bloom at a young age of two to three years. Usually, March to May and September to December, trees bloom twice a year.No leaf shedding, as it is a true evergreen tree, though the foliage gets thinner during protracted monsoons and dry season. Flowering - May. Seed formation - October. Fruit ripening - October-November.

Scientific classification:
Phylum: Spermatophyta
Sub Phylum: Angiospermae
Class: Magnoliopsida
Order: Santalales
Family: Santalaceae
Genus: Santalum
Species: album
Botanical name: *Santalum album Linn***.**

Distribution
Karnataka : Makarvalli in Hangal range, small blocks of Sandur, Huliyurdurga of Kollegal, Yedehalli of Bhadravathi, Coorg, Shimoga, Hassan, Kolar, Bangalore, Dharwar, Belgaum, North and South Kannada, Chickamaglur and Tumkur.

Tamil Nadu : Mainly in North Arcot (Javadis and Yelagiri hills), Salem, Periyar, Coimbatore, Vellore and sparsely in Nilgiris, Madurai and Trichy districts. Dense population is found in Chitteries, Jevadis, parts of Shevaroys and Tenmalai hills. **Santalum album associates**: *Pterocarpus santalinus, Anogeissus latifolia, Hardwickia binata, Cassia fistula* etc.

Site Factors: Climate : Mean annual temp. 17.8°C-33.8°C. and rainfall upto 1900 mm. **Topography** - It is a tree of upland plateau, growing chiefly on undulating ground but often on hill sides and in open places along the bank of rivers. Flourishes between altitude at sea level to 1250 m, but best growth is obtained at 375-1100 m elevation. **Geology and Soil** - Most commonly grows on red ferruginous loam, the underlying rock often being metamorphic, chiefly Gneis sand Igneous origin in Dharwar district. On typical black clayey soils in Madhya Pradesh, where the underlying rock is Deccan Trap.

Silvicultural Characters: Mainly occur in open scrub forests, hedgerows among Lantana bushes, bamboo clumps and round the edges of cultivated lands. Young trees coppice fairly well, older trees have little or no coppicing power except on moist ground along the banks of water courses. Seedlings are subject to attack of insects; hypocotyl and young leaves and taproots are readily attacked. Extremely fire-sensitive. Dense branches are capable of intercepting high velocities. Seedlings require lateral shade, but intolerant of low overhead cover. In its middle and later life, it is intolerant to heavy overhead shade. Seedlings are sensitive to drought as well as waterlogging.

Root-parasitism : It is a root-parasite i.e., numerous lateral roots establish their contact with the neighbouring roots of other host trees through the formation of haustoria. Out of large no. of associates, good host plants are *Cajanus cajan, Azadirachta indica, Pongamia pinnata, Cassia spp, Acacia spp, Melia dubia, Casuarina equisetifolia, Ficus benghalensis, Syzygium cumini, Terminalia spp, Lagerstroemia spp, Dendrocalamus strictus, Bambusa arundinacea, Albizia spp, Dalbergia spp* etc.

Silvicultural regeneration

Natural regeneration : Regenerate profusely through seeds and root suckers. Good seed year occur every year and germination take place during rainy season. The fruit-stone cracks, radicle emerges and seed is carried either above ground or left in the ground. Hypocotyl elongates, cotyledons break off remaining within the seed, above which young foliage develop quickly. Leaves are simple, opposite, exstipulate and earlier ones are smaller than the later ones. Important cultural operations for natural regeneration include maintainance of natural host plants, eradication of obnoxious undesirable weeds, protection of seedlings from drought and facility for free and natural expansion of crown. Seedlings grow better under partial shade. Seed collection and storage- Seeds are collected from fresh fruits and then dried under shade and the dry seeds are stored in polythene bags. No. of seeds in one kg is about 6000.

Seed Germination : Fresh seeds usually have a dormancy period of 2 months and viable up to 9 months. Seed takes 4 to 12 weeks to germinate after the dormancy period. Soaking seeds in 0.05% Gibberellic acid overnight and then sowing ensures uniform germination. Soaking the seeds for 24-48 hr sis reported to give 75 % germination.

Artificial Regeneration : It can be propagated by dibbling seeds under the bushes or on the mounds. By transplanting nursery raised plants and by vegetative propagation through air layering or through root suckers. Artificial regeneration of this species fails at times due to many reasons such as- Improper appreciation of obligate roots. Parasitic nature of the species. Selection of unsuitable tree species. Removal of host plants from the site. Sensitiveness of root system during transplanting. Inadequate measures against lopping, grazing, fire etc. Spike disease of Sandal First reported by McCarthy from Kushalnagar in 1891. In this disease, plant puts out stiff and erect bristles looking like a ‘spike’ with four lines or erect leaves growing down like a ‘chimney brush’. According to Venkata Rao (1935), the incidence of disease was highest in the scrub jungles where there is thick vegetation, while it was low in pole forest or open areas where undergrowth is less or scanty. Later Nayar and Srimathi (1968) confirmed that Lantana is a symptomless carrier of the disease. It was also felt that sandal in association with certain hosts was more susceptible to disease than others. Highest incidence of this disease is from May to July, with a peak in June.

Utilization Wood : Sapwood white and scentless, heartwood yellowish-brown and strongly scented. Heartwood is hard, close-grained, oily used for carving and other fancy work, distilled for fragrant oil called sandal oil. Sapwood, also called ’White wood’, is used for the manufacture of agarbattis. Depending upon its colour and grains, sandal wood is graded into four types-Red and White Sandalwood (based on colour) and the Snake and Peacock Sandalwood (based on grains). Fragrance of sandal is due to Santalol, a polyphenol. Sandal wood oil Powder of heartwood upon steam distillation yields the East Indian Sandalwood oil, which is esteemed high for its sweet, fragrant, persistent, spicy, warm, woody note, non-varying composition and fixative property. It is used in agarbatti, cosmetic, perfumery and soap industries. In medicine, it finds use as an antipyretic,

antiseptic, antiscabietic, diuretic, expectorant, stimulant and for treatment of bronchitis, dysuria, gonorrhoea and urinary infections.

Economic importance of sandalwood

Sandalwood (*Santalum album*) is a highly valued tree species renowned for its aromatic heartwood, which has been traded for centuries. The economic importance of sandalwood in forestry is substantial**.**

Timber : Sandalwood is prized for its durable, fragrant timber, used in furniture, carving, and construction.

Essential Oil : Sandalwood oil, extracted from the heartwood, is use in perfumery, cosmetics, and pharmaceuticals.

Medicinal Properties: Sandalwood has antibacterial, anti-inflammatory, and antiseptic properties, making it valuable for traditional medicine.

Incense and Aromatics: Sandalwood is use in incense sticks, powder, and chips for religious and cultural purposes.

Market Demand: Global Market Value: The global sandalwood market is projected to reach USD 1.5 billion by 2025. **Demand from Asia**: India, China, and Japan are significant consumers of sandalwood products. **Luxury Goods**: High-end perfumes, cosmetics, and furniture drive demand for sandalwood.

Benefits to Farmers: Additional income from intercrops (Rs. 50,000-100,000 per acre per year), Improved sandalwood growth and productivity due to shade and nutrient sharing, Reduced sandalwood mortality rates (10-20% reduction), Enhanced soil fertility and structure**,** Increased employment opportunities for rural labor, better risk management through diversified income streams.

Successful Sandalwood Intercropping Models:

1. Sandalwood + Rice + Pulses (Andhra Pradesh, India)
2. Sandalwood + Groundnut + Sunflower (Karnataka, India)
3. Sandalwood + Turmeric + Ginger (Tamil Nadu, India)

Conclusion

Indian sandalwood is one of the most auspicious and economically important tree species regarded as the “Royal Tree”in the Indian subcontinent. It is recommended that farmers only buy Quality Planting Material (QPM) stock from known seed sources. Sandalwood plants should only be purchased from nurseries that are accredited and certified. It's getting harder for farmers to keep their growing sandalwood trees safe. *Santalum album* required careful conservation and sustainable management. To ensure its continued availability for future generations, it is crucial to address its specific needs and challenges. Effective conservation strategies, research, and sustainable practices are vital for preserving this iconic Indian tree, maintaining its ecological, economic, and cultural significance.

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PURPLE WHEAT: A FUNCTIONAL GRAIN FOR HEALTH AND NUTRITION

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Abstract

The unique health advantages of purple wheat are primarily attributed to its high concentration of anthocyanins. These compounds not only contribute to the vibrant purple hue but also function as potent antioxidants. Anthocyanins effectively neutralize free radicals and mitigate oxidative stress, which are significant contributors to cellular damage and the aging process. Moreover, purple wheat bolsters the body's natural defense mechanisms by enhancing the activity of antioxidant enzymes such as superoxide dismutase (SOD) and catalase (CAT). Its ability to chelate harmful metal ions further reduces the formation of reactive oxygen species (ROS), safeguarding cellular components like DNA and lipids from oxidative damage. In addition to its antioxidant properties, purple wheat exhibits anti-inflammatory effects by modulating key pathways involved in inflammation. These combined benefits underscore its potential as a functional food ingredient to address oxidative stress-related conditions, including cardiovascular disease, diabetes, and neurodegenerative disorders, rendering it a promising candidate for nutraceutical and therapeutic applications.

Keywords: antioxidant, anthocyanin, DNA, wheat and heath

Introduction

A basic diet for billions of people worldwide, wheat is one of the most consumed grains. However, bioactive chemicals that provide health benefits beyond basic nutrition are not present in large amounts in typical wheat cultivars. In this regard, the enhanced antioxidant profile of colored-grain wheat varieties—especially purple wheat—has drawn notice, mainly due to anthocyanins. In 1870, the purple tetraploid wheat (Triticum durum) was first brought to Europe from Abyssinia, Ethiopia. Because purple wheat has the potential to produce cultivars that are beneficial to human health, the demand for purple wheat grain has increased significantly during the past two years. According to Sharma *et al.* (2019), 700 acres of purple wheat are grown in India, spanning from Patiala to Jalandhar in Punjab to Vidisha in Madhya Pradesh. The anthocyanin content of purple wheat makes it desirable (Lia *et al.* 2017; Grausgruber *et al.* 2018). While purple wheat has a high concentration of anthocyanin and other phytochemicals that are gaining attention globally these days, commonly consumed wheat (Triticum aestivum) is tawny in colour and has a low anthocyanin content (Sytar *et al.* 2018; Calderaro *et al.* 2019).

Numerous degenerative disorders, such as diabetes, rheumatoid arthritis, osteoporosis, cancer, cystic fibrosis, Alzheimer's disease (AD), Parkinson's disease (PD), and amyotrophic lateral sclerosis (ALS), have been linked to oxidative stress. According to Patel et al. (2013), these illnesses are distinguished by widespread oxidative damage to proteins, lipids, and DNA. Enhancing food's micronutrient content has emerged as a key area of the Second Green Revolution. Minor bioactive substances including polyphenols, pigments, and carotenoids have drawn increasing attention from

scientists and food manufacturers in recent years due to their potential to prevent disease and promote health in both in vitro and in vivo studies (Havrlentov *et al.* 2014).

A. Nutritional composition

Table-1: Proximate and bioactive components reported as the mean of three triplicate, PW is purple wheat flour (Kassegn, 2017)

Code	Moisture%	Crude Protein%	Crude Fat%	Crude Fiber%	Ash%	Carbohydrates	Energy(Kcal/g)
PW	10.76	8.53	3.03	7.33	5.5	64.85/72.2	320.77

Mean results of anthocyanin, gluten and anti-nutritional factor contents of purple wheat, catechin Eq.mg/100g and %, respectively					
Code	Total phenols content	Total con. Tannin	Total anthocyanin content	Gluten content	
				Wet(%)	Dry(%)
PW	253	25.6	197.4	16.7	5.7

B. Antioxidant Mechanisms: Antioxidants inhibit reactive oxygen species (ROS) and free radicals, which lead to oxidative stress, a major contributor to the emergence of chronic illnesses like diabetes, cancer, and cardiovascular diseases.

1. Free Radical Neutralization: The anthocyanins present in purple wheat possess the ability to donate hydrogen atoms or electrons, thereby neutralizing free radicals such as reactive oxygen species, including hydroxyl radicals, superoxide anions, and hydrogen peroxide. This process prevents chain reactions that could potentially damage cellular structures like DNA, proteins, and lipids.

2. Metal Ion Chelation: The polyphenolic compounds found in purple wheat have the capacity to bind with transition metal ions, such as Fe^{2+} and Cu^{2+}, which catalyze the formation of free radicals through the Fenton reaction. This chelation reduces the availability of these ions, consequently lowering oxidative stress.

3. Regulation of Antioxidant Enzymes: Anthocyanins play a role in upregulating endogenous antioxidant enzymes, such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx). These enzymes further contribute to the neutralization of free radicals, creating a synergistic effect.

4. Anti-Inflammatory Action: By reducing oxidative stress, anthocyanins indirectly suppress inflammation-related pathways, such as NF-κB signaling, thereby providing additional protection to cells and tissues from oxidative damage.

Health Benefits

1. **Rich in Anthocyanins (Antioxidant Properties):** Anthocyanins are potent antioxidants that give purple wheat its unique colour. By scavenging free radicals, which are unstable chemicals that can harm cells and cause chronic illnesses, these substances shield the body. Anthocyanidins help prevent diseases including cancer and Alzheimer's disease, promote skin health, and postpone ageing by lowering oxidative stress. Eating foods high in antioxidants, such as purple wheat, also improves cellular repair processes and reduces the incidence of inflammatory illnesses.

2. **Anti-Inflammatory Effects:** Purple wheat's anthocyanins and other bioactive substances have potent anti-inflammatory qualities. A prevalent underlying cause of conditions like metabolic disorders, cardiovascular illnesses, and arthritis is chronic inflammation. Anthocyanins shield tissues from harm by blocking inflammatory signals such as cytokines and enzymes that fuel inflammation. Frequent purple wheat consumption can enhance joint and muscle health and lessen inflammatory symptoms. This makes it a good nutritional option for people with diseases linked to inflammation.
3. **Improved Cardiovascular Health:** By raising good cholesterol (HDL) and lowering bad cholesterol (LDL), purple wheat promotes heart health. Purple wheat's anthocyanins help increase blood vessel flexibility, which enhances blood flow and lowers blood pressure. Together, these benefits lower the risk of heart attacks and atherosclerosis, or plaque accumulation in the arteries. Additionally, its antioxidant qualities shield heart cells from oxidative damage, guaranteeing cardiovascular health in general.
4. **Blood Sugar Regulation:** Due to its low glycaemic index, purple wheat does not result in abrupt increases in blood sugar levels. In order to facilitate a consistent flow of energy, the anthocyanins slow down the conversion of carbohydrates into glucose. Those who have type 2 diabetes or are trying to control their blood sugar levels will find this especially beneficial. Purple wheat's fibre content also slows down digestion, which helps to maintain blood sugar levels. Purple wheat can help minimise insulin resistance and the risk of diabetes when consumed as part of a balanced diet.
5. **Gut Health Improvement:** A healthy digestive tract depends on dietary fibre, which purple wheat is high in. As a prebiotic, the fibre feeds good bacteria in the gut and balances the intestinal microbiota. A balanced gut microbiota improves immunity, lowers inflammation, and facilitates digestion. Constipation and other digestive problems can be avoided by using purple wheat's fibre to assist control bowel motions. Purple wheat enhances gut health, which improves vitamin absorption and general wellness.
6. **Reduced Risk of Cancer:** Purple wheat is a useful component of a diet that prevents cancer because its anthocyanins have anti-cancer qualities. These substances stop cancer cells from proliferating and spreading by causing apoptosis, or programmed cell death. Additionally, anthocyanins lessen DNA damage brought on by free radicals and prevent pathways that encourage the growth of tumours. Their efficacy in lowering the risk of malignancies like prostate, breast, and colon has been demonstrated by studies. Regular consumption of purple wheat may provide protection against several types of cancer.
7. **Supports Weight Management:** Complex carbs and fibre, which are present in purple wheat, help to lessen hunger pangs and increase feelings of fullness. Purple wheat helps avoid overeating because, in contrast to refined grains, it delivers steady energy without triggering sharp spikes in blood sugar. Because of this, it's a great choice for people who want to keep or lose weight. By promoting intestinal health, the fibre content also improves metabolism, which helps control body weight. Purple wheat can help with long-term weight control when combined with a healthy lifestyle.
8. **Neuroprotective Effects**: Emerging evidence indicates that purple wheat anthocyanins protect neurons from oxidative damage, potentially reducing the risk of neurodegenerative diseases such as Alzheimer’s and Parkinson’s.

Conclusion

The increased anthocyanin content and antioxidant qualities of purple wheat make it stand out as a potential cereal crop with substantial health benefits. Purple wheat differs from regular wheat in that it has more bioactive substances, such as flavonoids, anthocyanins, and phenolic acids, which help prevent and treat chronic illnesses like diabetes, cancer, heart disease, and neurological problems. Given its distinct antioxidant mechanisms and capacity to function as a natural pigment source, it is a prime choice for the development of functional foods. Purple wheat's rising popularity is a reflection of the global movement to include more nutrient-dense foods in daily diets in order to improve health results. Purple wheat has a great deal of promise for improving functional food innovation and tackling global health issues. In order to ensure a better and more resilient future, purple wheat can be crucial in encouraging nutrient-dense diets and battling chronic diseases as consumer awareness of sustainability and health grows.

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INNOVATIVE TECHNOLOGIES FOR QUALITY IMPROVEMENT UNDER CONTROLLED CONDITIONS

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Abstract
Innovation in crop yields, quality, and consistency is required to meet the growing demand for premium veggies. Modern technology for controlled quality improvement are demonstrated in this presentation, revolutionising the field of vegetable farming. The exploring the various technologies including LED-based lighting systems, precision irrigation and nutrient management, climate control and air quality management, artificial intelligence and machine learning, vertical farming and hydroponics. These technologies potential to improve crop quality and consistency, increase yields and reduce waste, enhance sustainability and reduce environmental impact, support year round production and reduce seasonal fluctuations.

Keywords: Protection technologies; quality improvement; sustainable agriculture; vegetable production; controlled conditions.

Introduction

Protected vegetable crop cultivation The greenhouse is a frame building with transparent materials like polycarbonate, glass, and polyethylene covering it. The first individual to employ polyethylene as a greenhouse cover was Emery Myers Emmert. The 'Greenhouse effect' refers to the phenomena of solar energy being trapped within the playhouse. Capsicum, tomato, lettuce, and other high-value vegetables can be grown in the greenhouses. Since greenhouse farming is very intensive, low-volume, high-value crops can be the most profitable to cultivate in the playhouse. Glazing is the term used to describe the greenhouse's covering. Glass houses are quite common in the Netherlands. Because they receive the most sunshine, gable-roofed or triangular-roofed greenhouses are among the most popular forms of greenhouses. The [uneven-span] gable type greenhouse structure is best suited for hilly areas.

Protected cultivation is necessary

With a total of around 113.5 million tons, Indian horticulture has significantly increased vegetable production and is now second only to China. However, by the end of 2024, it is predicted that the annual demand for vegetables will be around 135 million tons. The real cause of the low output and productivity has been identified as the year round temperature extremes, which range from 0 to 48 degrees Celsius and prevent year round outdoor vegetable growing. Cold desert conditions predominate in the upper Himalayas, where winter temperatures range from 5 to 30 degrees

Celsius. The areas are isolated from the rest of the nation from November to March because of heavy snowfall, making it challenging to grow vegetables. Because there are so many vegetables available in the markets during the growing season, vegetable farmers do not receive high prices.

Safeguarded Buildings

The various kinds of protective structures that are employed in this sector include:

1. Plastic mulch : Mulching is the process of covering the area surrounding a plant to improve soil structure preservation, moisture conservation, weed control, and CO2 exchange for the root system, all of which promote plant growth. Because the fruits don't come into contact with the earth, it enables cleaner crop production. Films with silver and yellow hues work well to keep insects like white flies and aphids away. Because of their opacity, black polyethylene mulches are more widely used.

2. Net-houses : These come in two varieties: insect-proof nets and shade nets. To reduce solar radiation and prevent crops from wilting or scorching, shade nets are utilized. Black, green, and white are the three colors that are available for these, and they come in a range of shading strengths from 25 to 75%. There are several intensities of insect-proof nets, ranging from 25 to 60 mesh. For suppressing the majority of flying insects, nets with a mesh size of 40 or more work well. Breeding programs also use these for regulated pollination.

3. Low tunnels and row covers made of plastic : Transparent plastic film stretched over steel hoops that are roughly 50 cm high and 1 m wide is used to cover plant rows in open fields. A 30–50 micron thick polyethylene film is utilized. Another name for these is small greenhouses. Because they retain heat, they shield crops from the damaging effects of frost. They accelerate early market expansion, particularly in cucurbits.

4. Covers made of floating plastic : To shield vegetables from cold temperatures and snow or frost, huge open fields are covered with a clear plastic sheet.

5. The walk-in tunnels : These are straightforward constructions that are often arc-shaped, with a center height of 2 to 2.5 meters and a width of roughly 4 meters. These can hold nearly two or three vegetable beds and are appropriate for low-canopy crops like lettuce, bush-type beans, capsicum, and others. They can also be raised in nurseries.

6. Trenches in the soil : In harsh winters, a trench is an easy and affordable way to raise crops. An alternative name for them is underground solar greenhouses. They are typically 5 to 6 meters wide and 2 to 3 meters deep. Vegetables are grown via trench cultivation, which uses soil and solar heat. In the chilly desert regions, particularly Ladakh, they are highly well-liked.

7. Warm beds:

The basic idea behind traditional hotbeds is that even in extremely cold temperatures, crops can be grown using the heat produced by the breakdown of manure. Straw and partially rotting manure are alternately spread out on the ground to create these. These are appropriate for nursery rearing throughout the off-season.

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Figure 1: Various types of protective shed

Greenhouses are categorized according to their shape:

1. Lean-to-type : Green houses are those that are positioned up against the side of another building. Thus, it shares a wall with another building that serves a different purpose and has a single-sloping roof. Lean to green houses are the least expensive and are regarded as traditional buildings.

2. Even-span type: A greenhouse is built on level ground with a roof pitch or breadth that is the same on both sides.

3. Uneven-span type:

A greenhouse with different roof pitches or widths on each side. One roof's slope is longer than th e other's. Most appropriate for hilly areas.

4. Ridge & Furrow type: This form of community is joining along the length of the eaves and consists of green houses with even spans. Eaves act as a gutter or trench to remove melted snow and rain.

5. Sawtoothed type: Roof ventilation is the most crucial component in the construction of these commercial green houses.

6. Quonset/Arch roofed type:

A greenhouse with pipe purling along the length of the structure to support pipe arches or trusses. Polyethylene is a common covering material that is useful when a limited, isolated cultivated area is needed.

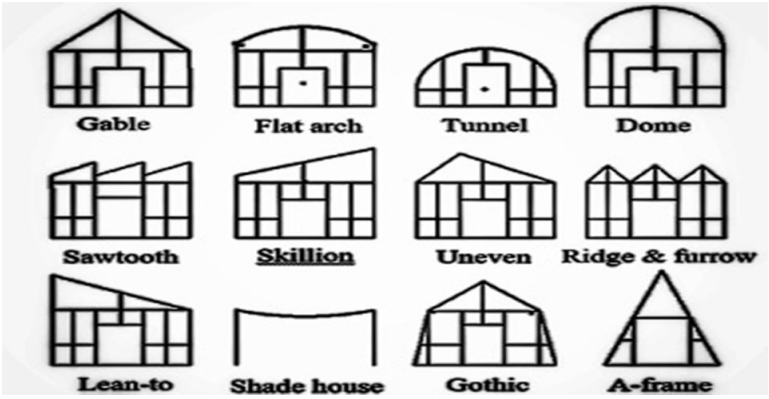

Figure 2: Categories of greenhouse shapes

Advantages of Protected Vegetable Crop Cultivation

a) Comparing particular values of an instrument's input and output with a matching reference standard is known as calibration.
b) Production schedules for horticulture and agriculture can be set to capitalize on market demands.
c) Four to five crops can be produced in a greenhouse all year round. There is a significant boost in crop yield and financial return per unit area.
d) An infrared gas analyzer is the most widely used sensor for measuring CO_2 in greenhouses (IRGA).
e) Alcohol is the that is used in the minimum thermometer to measure temperatures, The Thermistor is capable of measuring temperatures between -100^0C and 300^0C.
f) Diseases and pests can be effectively controlled, In greenhouses, a large percentage of seeds germinate.
g) The temperature within the greenhouse is also measured using in infrared thermometer, Psychrometers and hygrometers are devices that measure relative humidity.
h) Produce of superior grade is available. It is possible to pursue high quality seed production features. A greenhouse can be used to acclimate plantlets to the tissue culture procedure.
i) Farmers with modest holdings are most suited for greenhouses. It is labor-intensive and contributes to the creation of jobs in rural areas.

Conclusion

Vegetable producers may now enhance crop quality, boost yields, and lessen their environmental impact thanks to the incorporation of cutting-edge technologies under carefully monitored settings. Growers can optimise resource utilisation, predict and prevent disease outbreaks, and create ideal growing conditions by utilising advanced technologies like LED-based lighting systems, precision irrigation and nutrient management, climate control and air quality management, artificial intelligence and machine learning, vertical farming, and hydroponics. The benefits of innovative technologies including improved crop quality and consistency, increase yield and reduced waste, enhanced sustainability and reduced environmental impact.

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