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# MACHINE LEARNING AND HYPERSPECTRAL SATELLITE IMAGING: A NEW ERA IN CROP TYPE MAPPING

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Agriculture faces unprecedented challenges today due to the twin pressures of climate change and the global demand for food security. To address these, scientists and technologists are increasingly turning to machine learning and innovative satellite imaging technologies, specifically hyperspectral data from new-generation space borne platforms (Meng *et. al.,* 2021). These advancements are transforming the field of crop type mapping, providing a revolutionary way to monitor and manage crop landscapes in a timely and precise manner. This approach to crop type mapping goes beyond traditional methods, which often relied on limited field data and slower analysis processes. With satellite-based hyperspectral data, farmers and agronomists can monitor vast agricultural landscapes remotely and receive real-time, high-resolution insights that facilitate precision agriculture. As machine-learning algorithms evolve, they will increasingly help predict seasonal yields, guide resource allocation, and optimize planting schedules tailored to specific environmental conditions and crop needs (Aneece *et. al.,* 2024, Pandya & Gontia, 2023).

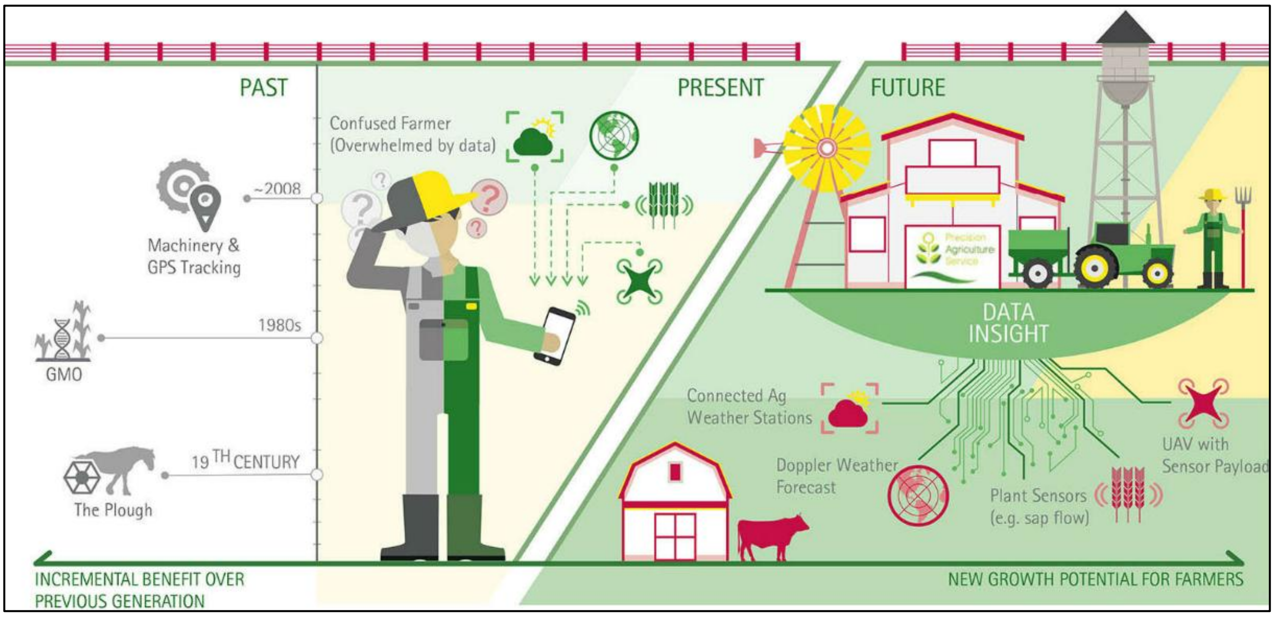


Figure 1: Revolution of Agricultural Technology: From Traditional Tools to Data-Driven Precision Farming

In the future, these technologies will enable more efficient and sustainable agricultural practices by minimizing resource wastage, reducing reliance on chemical inputs, and enhancing resilience against climate-related impacts. Hyperspectral imaging combined with machine learning could lead to breakthroughs in crop management, ultimately supporting food security and promoting climate-resilient agricultural systems (Hirapara *et. al.,* 2024). As the accessibility of hyperspectral satellite data increases, these advancements will likely become integral to agricultural monitoring systems worldwide, paving the way for a more sustainable and food-secure future (Pandya & Gontia, 2023).

**The Significance of Crop Type Mapping**

Accurate crop type mapping allows for better tracking of agricultural trends, yield estimation, and overall food security planning. By understanding, what crops are being grown, where, and at which rate, policymakers and farmers can make informed decisions on resource allocation, trade, and environmental protection. Traditional methods for crop mapping, such as field surveys and manual interpretation of satellite images, are often time-consuming, expensive, and limited in spatial coverage (Sharma *et. al.,* 2024).

However, with advancements in remote sensing, machine learning and Artificial Intelligence, especially with hyperspectral imaging, it is now possible to map crop types with unprecedented accuracy. Unlike conventional multispectral sensors, which capture a limited number of broad bands (usually three to twelve), hyperspectral sensors acquire dozens or even hundreds of contiguous spectral bands. This high level of spectral detail allows for the differentiation of crops based on subtle differences in their biochemical and physiological properties, offering a detailed "spectral fingerprint" for each crop type (Aneece *et. al.,* 2024, Hirapara *et. al.,* 2024)

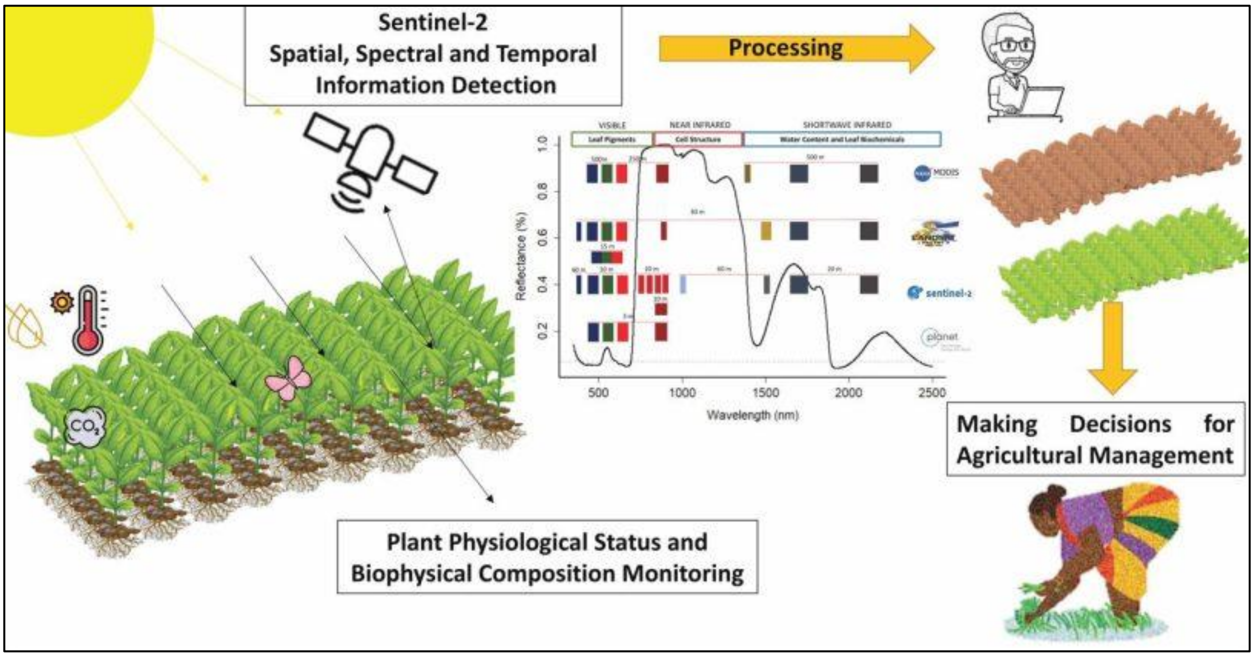


Figure 2: Remote sensing and GIS technologies for crop identification

**Hyperspectral Imaging: A New Dawn for Agricultural Monitoring**

The new generation of space borne hyperspectral sensors, such as those on board platforms like Sentinel mission, Landsat mission, German EnMAP mission and the newly launched NASA Surface Biology and Geology (SBG) mission has specially designed to capture detailed spectral information across visible and infrared wavelengths. This data provides a deeper understanding of plant characteristics such as leaf pigmentation, water content, and cellular structure. These hyperspectral images enable fine-scale crop type mapping by capturing variations that multispectral sensors cannot detect. The technology can differentiate not only between major crop types (like wheat and corn) but also among varieties within the same crop type, enabling an incredibly detailed and nuanced view of agricultural landscapes (Zoungrana *et. al.,* 2024).

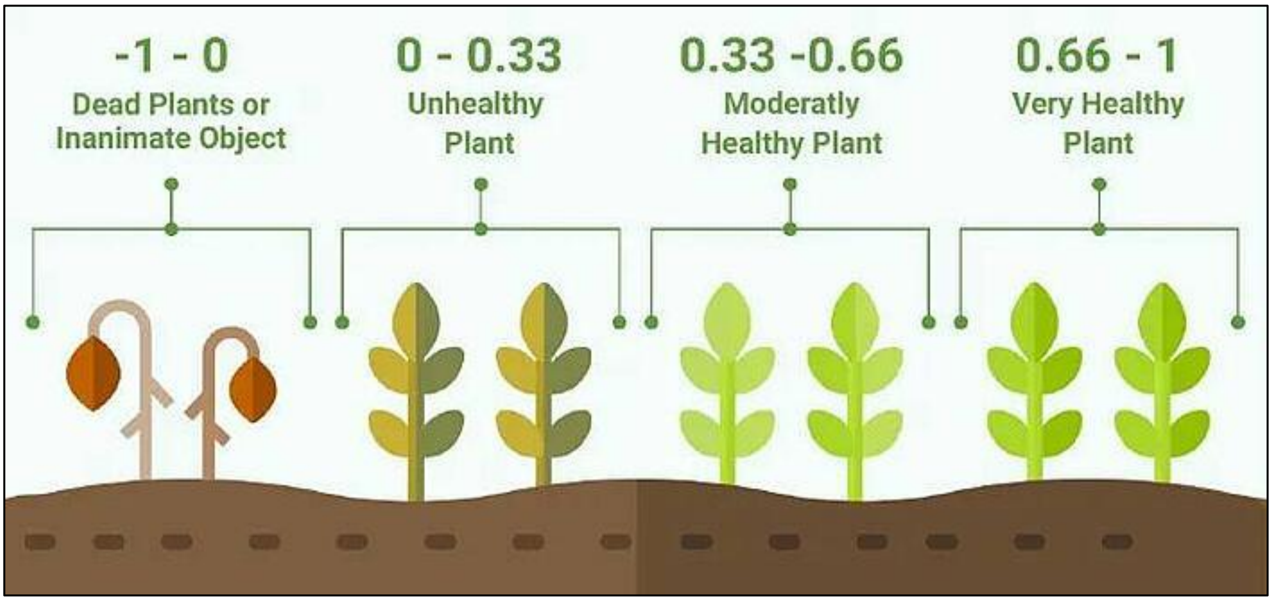


Figure 3: Electromagnetic spectral signature range of various crop growth stages

**Machine Learning's Role in Crop Identification**

While hyperspectral data offers a wealth of information, translating it into actionable crop maps is a challenge. This is where machine learning (ML) becomes invaluable. Advanced ML algorithms can analyze massive datasets, discerning complex patterns that may not be evident to the human eye. In crop type mapping, ML techniques such as convolutional neural networks (CNNs), support vector machines (SVMs), and random forests has employed to classify and map different crops accurately. The process begins with a training dataset—field samples of various crop types labeled and matched with hyperspectral data. ML algorithms use this dataset to learn the spectral characteristics of each crop. Once trained, the model can classify crop types across vast agricultural areas with high precision, even detecting the subtle differences among varieties within a crop type (Attri *et. al.,* 2024).

**Practical Applications and Global Implications**

The fusion of machine learning and hyperspectral data has the power to revolutionize agricultural monitoring worldwide. Some key applications include:

1. **Enhanced Yield Prediction:**

   Accurate crop type maps serve as the basis for yield prediction models. By knowing the specific crop type, growth stage, and health status, researchers can better predict potential yield outcomes, allowing governments and organizations to respond more effectively to food shortages.

2. **Sustainable Resource Management:**

With precise data on crop types, farmers and agricultural planners can make better decisions regarding water usage, pesticide application, and soil conservation, leading to more sustainable agricultural practices and reduced environmental impact.

**3. Climate Resilience and Food Security:**

Accurate crop mapping aids in tracking crop rotation patterns, enabling better understanding of how climate shifts affect crop growth. This information is vital for developing resilient agricultural practices that can withstand changing climate conditions and mitigate the risks to global food security.

**4. Precision Agriculture:**

Farmers can benefit from crop-specific insights, allowing them to optimize fertilization, irrigation, and pest control tailored to each crop is needs. This improves efficiency, reduces costs, and minimizes environmental damage.

## Challenges and Future Directions

Despite these advancements, some challenges remain. The immense size of hyperspectral datasets poses computational challenges, especially for real-time applications. Additionally, cloud cover can obstruct satellite imagery, limiting the effectiveness of hyperspectral mapping in certain regions and seasons. Researchers are working on integrating ground-based sensors and drone-mounted hyperspectral cameras to complement space borne data, which could help overcome these limitations.

Another focus is developing ML algorithms that can handle the "curse of dimensionality"—the high number of spectral bands in hyperspectral images. Dimensionality reduction techniques, like principal component analysis (PCA), Linear Discriminant Analysis (LDA), Multidimensional Scaling (MDS) and Independent Component Analysis (ICA), are crucial in managing the vast amounts of data generated by hyperspectral sensors (Parthsarthi *et. al.,* 2022). These techniques simplify complex datasets by reducing the number of spectral bands, making data processing more efficient and computationally feasible. However, this simplification can come at a cost. When certain bands are combined or removed, some of the unique information that distinguishes one crop type from another may be lost, potentially affecting the accuracy of crop classification. Researchers are therefore actively exploring alternative methods that retain as much valuable information as possible while ensuring the data remains manageable.

## Conclusion: A Path to Agricultural Transformation

The integration of machine learning with new-generation space borne hyperspectral data represents a promising frontier in crop type mapping and, more broadly, in agricultural technology. By providing the means to monitor crop landscapes with an unprecedented level of detail, these tools could significantly enhance our understanding and management of global agriculture, paving the way for a more sustainable and food-secure future. As these technologies continue to mature and become more accessible, we may soon see a world where crop type mapping is as routine as weather forecasting—empowering stakeholders at all levels to make informed, timely decisions that benefit both agriculture and the planet.

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# ULTIMATE GUIDE TO GARDEN PEA FARMING

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**Abstract**
The garden pea is one of the most extensively planted leguminous crops, with nutritional, economic, and agricultural benefits. Its cultivation extends back to antiquity and remains an important part of global food systems. Garden peas thrive in cool-season conditions, making them ideal for temperate regions or winter crops in subtropical zones. Pea prefer well-drained, fertile soils with a pH of neutral to slightly alkaline (6.0-7.5). Proper land preparation, such as ploughing and levelling, promotes optimal seed germination and root development. Sowing is normally done in rows, with adequate space to improve ventilation and reduce disease concerns. Rhizobia is introduced into seeds to improve nitrogen fixation and soil fertility. Garden peas help to promote sustainable agriculture by enhancing soil health through nitrogen fixation and functioning as a rotation crop. Garden peas have considerable promise in both conventional markets and modern food innovations, given the growing demand for plant-based protein. This overview emphasises the relevance of research and development in optimising farming practices for increased production and sustainability.

**Introduction**
The garden pea (*Pisum sativum* L. var. *hortense*) is a significant legume vegetable grown for its nutritious, fresh, green, shelled seeds. It is a basic cool-season, frost-resistant, protein-rich (7.2%) legume that is widely grown for its green pods, seeds and foliage all over the world. India ranks second to China in terms of both area and production. In India, it is grown on 0.61 million hectares, yielding 6.62 million metric tonnes with a productivity of 10.89 t/ha. Garden pea is a cool season crop that is grown primarily in the plains during the winter and in the hills during the summer. Garden pea is most grown in the country's temperate and subtropical regions. It is also grown in the cooler regions of southern India. Garden pea is widely cultivated in states such as Uttar Pradesh, Madhya Pradesh and Jharkhand. It is also cultivated in Himachal Pradesh, Punjab, West Bengal, Haryana, Bihar, Uttarakhand, Jammu & Kashmir, Odisha, and some parts of Rajasthan and Maharashtra. In the south, it is grown in Karnataka and hilly areas like as Ooty and Kodaikanal. Aside from having a low iron content, it is high in protein (25%), amino acids, sugars (12%), carbohydrates, vitamins A and C, calcium and phosphorus. Peas are an important vegetable since they contain a high protein content. It can be used as dehydrated, frozen, canned vegetable or soup.

**Soil and climatic condition**
To grow peas, we can utilise light sand, silt loam, or clay soil. Early crops thrive in sandy loam soil. If earliness is not an issue, well-drained clay loam or silt loam is recommended for high yields. The crop can be produced in well-drained soil rich in organic compounds. The optimal soil pH for growth is 6.0 to 7.5. Acidic soils do not promote pea growth. It is particularly sensitive to salinity and alkalinity. Liming can elevate the pH of soil that is less than 6.0. Peas are a cool season crop that

thrives in a chilly, slightly humid environment. Despite its low germination rate, the seed may sprout at a minimum temperature of 50°C. The optimal temperature for germination is 18 to 22 degrees Celsius. Seedlings suffer at temperatures above $22^0$ C. The optimal temperature range for growth and development is $13\text{-}18^0$ C. Growth stops at temperatures ranging from 29 to $30^0$ degrees Celsius. Pea seedlings can tolerate frosts of up to -20 degrees Celsius, although the plant suffers later in blooming and fruit development. A hot time is more harmful than a light frost.

**Seed rate, spacing and sowing time**

Tall varieties - 70-80 kg/ha & 30-45 x 10 cm. Dwarf varieties - 100 kg/ha & 22.5 x 10 cm. Depth: 4-5 cm. Cropping System-In general, peas are sown after harvest of kharif crops. The most common rotations are maize – pea; paddy – pea – wheat – (being popular in Northern India); cotton – pea; jowar – pea; and bajra – pea. Intercropping It can be sown as intercrop with autumn sugarcane as two rows of pea at 30 cm row spacing in the centre of two sugarcane rows at 90 cm apart. Sowing Time is 15th October to 15th November.

**Seed Treatment**

Seed Treatment Soaking seeds in GA3 (10ppm) for 12 hours results in high germination. To guard against fungal infection, pea seeds should be treated with 1g of Bavistin (Carbendazim), 2g of Captan (Captaf), or a talc-based formulation of Pseudomonas fluorescens @15g+1g Captan per kg seed before sowing. To treat pea seeds, utilise *Rhizobium leguminosarum* (a Rhizobium culture). In addition to fixing atmospheric nitrogen, this will reduce the amount of nitrogen in fertilisers. Under acidic conditions, it is beneficial to inoculate pea seeds with both the fungi Rhizobium and AM. Dual inoculation of pea seed with the cultures boosted crop yield and quality while saving around 25% on each type of fertiliser (N and P). Before sowing pea seeds, the cultures should be treated using the seed treatment method. Overnight, soak the required quantity of seeds in water. The seeds should be treated with Rhizobium culture shortly before sowing and then dried in the shade for about 30 minutes. The seeds are then allowed to dry in the shade for 30 minutes after being thoroughly mixed with a slurry containing AM fungal culture, rich soil, and water in a 1:1:4 ratio.

**Important varieties**.

1. **Ageta:** It is suitable for early sowing. First flower appears in about 25 days after seed sowing, and it takes about 6 weeks for first picking. Two picking are done. Average green pod yield is 50-55 q/ha.
2. **Alaska:** Early, smooth-seeded green pea. Pods are light green and appears singly with from England 5-6 small, bluish green. 55 days to maturity.
3. **Arka Ajit:** Resistant to powdery mildew and rust. Yield 10t/ha in 90 days.
4. **Arkel:** This is early maturing variety. Pods are dark green, 8.5 cm long, 7-8 green seeds per pod, incurved towards the sutures. First picking in 55-60 days. Pod yield 7.5 t/ha. Shelling percentage is 40%.
5. **Asauji:** Pods are about 8 cm long, curved, dark green, narrow and appear round when fully developed, each pod contains 7-8 seeds. Pods give high shelling percentage (45%).
6. **Azad Pea 2**: It is a powdery mildew resistant variety. Pods are medium in size, light green, straight, smooth, borne in cluster of two with 67 wrinkled and brownish seeds. This variety has average yield potential 120 q/ha.
7. **Azad Pea 3:** Early maturing variety (50-55 days), pods are long (9-9.5cm), dark green, 7-8 green seeds per pod, shelling percentage is 47%. Pod yield 7 t/ha.

8. **Bonneville:** This variety is introduced variety from USA (*released by IARI*) and recommended for cultivation in main season. Plants are medium tall (60 cm), flowers are mostly borne in doubles, and pods are light green, erect, contain 6-7 well-filled, sweet, bold and wrinkled seeds. It is susceptible to powdery mildew disease. The average green pod yield is 90 q/ha.
9. **Early Badger:** A dwarf wrinkled seeded variety. Pods are ready for picking in 60-65 days, pods are yellowish green and borne singly, 7.5 cm long with 5-6 bold and sweet seeds.
10. **Early Superb**: Yellowish green foliage. These are dark green, curved pod with 6-7 smooth seeds. Shelling percentage is 40%.
11. **Hisar Harit (PH1).** Plants are semi dwarf, green foliage green and single to double podded. Pods are well filled, sickle shaped, larger in size and green. Seed show dimpled after drying. Average pod yield is 90 q/ha·
12. **Hisar Harit (PH1).** Plants are semi dwarf, green foliage green and single to double podded. Pods are well filled, sickle shaped, larger in size and green. Seed show dimpled after drying. Average pod yield is 90 q/ha·
13. **Jawahar Matar 4:** Developed at Jabalpur through advanced generation selections from the cross (JM 4) Jabalpur T19 x Little Marvel. Plant height 65 cm, foliage and stem are green. First picking after 70 days. Pods are green, medium in size (7cm) with 6-7 green, wrinkled and sweet seeds. Average pod yield 7 t/ha with 40% shelling.
14. **Jawahar Matar-3:** Plant height 70-75 cm with bushy growth habit; flower colour white. First picking 50 days, pods 7 cm long, light green, roundish oval in shape with 4-5 wrinkled seeds. Shelling percentage (45%).
15. **Jawahar Peas 54:** Plants are dwarf and vigorous. Pods are round to oval shaped, 5 cm long, curved (sickle shaped) and enclosing 8-9 big, wrinkled, greenish-yellow seeds. Shelling percentage is 45. Average pod yield 7 t/ha. Recommended for zones IV, V, and VII.
16. **Jawahar Peas-4:** This powdery mildew resistant and wilt tolerant variety medium size pods with 5-6 bold, green seeds. First picking after 60 days in hillocks and 70 days in plains. Average pod yield 3-4 t/ha in hillocks and 9 t/ha in plains.
17. **Kashi Kanak:** It is an early maturing variety developed through selection. It has plant height 50-55cm, foliage dark green, pod straight, light green, length 7-8 cm filled with bold seeds. First picking at 55-58 days after sowing, green pod yield 60-80 q/ha.
18. **Kashi Mukti:** It is an early maturing powdery mildew resistant variety. Plant height is 50-53 cm and 50% plants bear flowers at 35-36 days after sowing. Pods are 8.5-9 cm long, attractive filled with 8-9 bold soft textured seeds, selling percentage 48-49 and yield 110-120 q/ha.
19. **Kashi Nandini:** Plant height is 47-51 cm, first flower 32 days after sowing, bears 7-8 pods per plant. Pods are 8-9 cm long, attractive, length 8-9 cm, well filled with 8-9 seeds, shelling percentage 47-48; yield 110-120 q/ha. It is tolerant to leaf miner and pod borer.
20. **Kashi Samridhi:** Resistant to powdery mildew. Plant type semi-determinate with dark green pods, medium maturing, No. of seeds per pod is 7-8, average yield 125 q/ha.
21. **Lincon:** It is also an introduced variety from US Are leased at Regional Research station, IARI, Katrian. Plants are medium tall and double podded. Pods are dark green, curved,8-9cm long with 8-9 wrinkled seeds. It is a good canning purpose variety. Average pod yield is 100 q/ha.
22. **Matar Ageta 6:** Early season dwarf variety. Tolerant to high temperature. Yield 6 t/ha with 44.67% shelling percentage. Seeds smooth and green.

23. **NDVP 8:** Mid-season variety with 10 t/ha.
24. **Pant Matar 2 (PM-2):** Pods are green, relatively small in size with 6 sweet and wrinkled seeds. It is also highly susceptible to powdery mildew. Its green pod yield is 70-80 q/ha.
25. **Pant Matar 2 (PM-2):** Pods are green, relatively small in size with 6 sweet and wrinkled seeds. It is also highly susceptible to powdery mildew. Its green pod yield is 70-80 q/ha.
26. **Pant Uphar (IP-3):** Plants are medium tall with light green foliage bear white flower. Pods are round, 7-8 cm in length, yellowish and contain wrinkled seeds. It is susceptible to powdery mildew disease, but resistant against pea stem fly. Green pod yield is 100 q/ha.
27. **Perfection New Line:** It is introduced from USA (*released by IARI*). The plant is vigorous, medium tall and flowers are borne in doubles. Pods bear length of about 8cm and are dark green containing 6- 7 light green, sweet and wrinkled seeds. Average pod yield is 100 q/ha.
28. **Punjab 88:** Early season variety developed through selection from cross between Pusa 2 x Morrasis 55. Pods dark green, long (8-10 cm) and slightly curved. Yield 15 t/ha with 47% shelling percentage.
29. **Punjab 89 (P-89):** The plants of this variety are medium dwarf, vigorous having more number of well filled pods. The pods borne in doubles and are dark green, 9 cm long bearing 8-9 wrinkled green seeds. The variety is highly susceptible to powdery mildew. Average green pod yield is 150 q/ha·
30. **VL-Ageti Matar-7 (VL-7):** Pods are light green, slightly in curved, 8cm long on taining 6-7seeds.The seeds are wrinkled and light green in colour. Its green pod yield is 90-100 q/ha.

**Field preparation and sowing**

To prepare the land well in advance, it is tilled at least four or five times to a good tilth. A significant amount of atmospheric nitrogen fixation is made possible by increased root growth and distribution, which necessitates careful ground preparation. Spreading well-rotted organic manure—ideally FYM or compost—at a rate of 15–20 t/ha is recommended when preparing the land. Two techniques are available for sowing:

**1. Ridge Sowing:** This method is especially important for early crops that are seeded from the last week of September to the first week of October. A Seed-cum Fertiliser pea drill should be used to plant peas on ridges 60 cm wide. This drill is used to plant two rows of peas, 25 cm apart, on each ridge. Ridge planting has advantages for an early crop. Seeds take several days to germinate, and irrigation is often required to keep the soil at the right moisture content. Because the water cannot pass over the ridges in this scenario, preemergence watering does not cause crust growth.

**2. Flat Sowing:** Because stream watering often results in crust development, which prevents aeration and nutrient uptake by the plants and ultimately leads to yellowing and limited plant growth, flat sowing requires the proper soil moisture condition or wet condition. Additionally, flat sowing should not be used in medium to heavy textured soils. Additionally, when manually selecting, there is not enough room.

**Water requirement**

Peas have a relatively low water need. If the soil is dry, pre-sowing irrigation is necessary for effective germination since seeds should be placed in the right amount of moisture. After 15 days of seeding, the first irrigation should be given. The type of soil and winter precipitation determine how often to water after that. For peas, light irrigations should be applied every ten to fifteen days.

Critical phases include flowering, fruit set and grain filling; crops should be carefully irrigated at these times. Lack of soil moisture inhibits nodulation and slows development. Furthermore, the production and quality of pods are limited by moisture stress during flowering and the succeeding pod-filling stages.

**Manure and fertilizer**

Twenty tonnes of farmyard manure, 25 kg of nitrogen, 70 kg of phosphorus and 50 kg of potash are needed per hectare to produce a productive crop of garden peas. Nitrogen fixation and nodule formation are negatively impacted by high nitrogen concentrations. By enhancing nitrogen fixation capacity and nodule formation, phosphoric and potassium fertilisers enhance yield and quality. Fertiliser should be applied 6–7 cm away from the seeds, with a 1.5 cm strip placed 1.5 cm deep. The seeds will be harmed if the fertiliser gets in contact with them. Using 40 kg of sodium molybdite per acre boosts production and builds cervical rot resistance. 15 kg of zinc sulphate should be applied per hectare if the soil is zinc deficient.

**Inter culture practices**

For two-hand weeding at three and six weeks after germination, the field pea crop should be weed-free for 40–50 days following sowing. In essence, an integrated weed management system (IWMS) combines practical, reliable, and efficient weed control techniques—such as mechanical, chemical, biological, and cultural methods—that growers may use profitably as a component of a good farm management system. Weed competition continues to be a problem for the crop during its early growth, with the important phase of crop weed competition occurring 30 to 45 days after sowing. Unchecked weeds can reduce yield by as much as 47%. Later, the crop itself covers the ground, suffocating weeds. *Chenopodium album* (bathua), *Fumaria parviflora* (gajri), *Lathyrus* species (chatri-matri), *Melilotus alba* (Senji) and *Viciasativa* (ankari) are the main weeds that are found in pea crops. It is challenging to distinguish vicia seeds from pea seeds. Thus, a significant issue in pea production. Thistle, or Carthamus oxycantha Bieb, is another pea weed that can be problematic. Pea harvesting is challenging due to its spiny nature. Because it trails on peas, *Convolvulus arvensis* L. causes major issues for its culture. After three and six weeks after germination, two weedings and hoeing will be performed to keep the fields free of weeds. For efficient weed control, apply Pendimethalin pre-emergence at a rate of 1 kilogramme a.i. /ha in 800 litres of water.

**Insect pest and disease management**

**Pea Aphid (*Acyrthosiphon pisi*):** It is among the pea crop's most dangerous pests. Aphids begin attacking in January. Young vines are attacked by the green, soft-bodied nymphs and adults, which also drain the sap from the younger plant sections. The afflicted plants become stunted, and the pods fail to fill, curl, and have rough patches. Spraying of Dimethoate 30 EC @ 1 ml/l or Cyantraniliprole 10.26 OD @ 0.6 ml/l of water for effective control.

**Pod Borer (*Helicoverpa* spp.):** Green pods are more severely affected by the illness, particularly when they reach maturity. The caterpillars consume the seeds after boring into the pods. The harm caused by pests is minimised when the caterpillar and pupa are hand-picked in the early stages of infestation. Crop Spray with Azadirachtin 0.03% (300ppm) thrice at 15 days intervals.

**Leaf Miner (*Phytomyza atricornis*):** It is a serious pea pest. By creating serpentine mines where air becomes trapped and gives them a silvery look, the larvae assault delicate leaves and feed on the leaf's epidermal layers. The impacted leaves crumple, twist, and turn pale yellow. These leaves eventually dry out and disappear. It is very helpful to spray Dichlorvos (0.05%) on the plants as soon as new leaves appear. Spray dimethoate 30 EC @ 1 ml/l of water and repeat spray at 10 days interval.

**Stem Fly (*Ophiomyai phaseoli*):** One of the biggest pea pests is the stem fly. The plants wilted because of the maggots boring inside the stem. Apply phorate 10G @ 7.5 kg or carbofuran 3 G @ 25 kg of per ha in furrows at the time of sowing. The crop spray with insecticide like oxydemeton methyl 25 EC @ 750 ml per ha in 750 liter of water.

**Powdery Mildew** (*Erysiphe polygoni*): It is an important disease of pea. The disease manifests on the leaves as well as pods. It attacks on leaves first small discoloured formed and white mycelium growth developed. The entire leaf area is covered by these enlarged patches and white powdery growth of mycelium spread over stem and pods. Before they fall, severely infected leaves may turn deformed and chlorotic. Spray the crop with Karathane (Dinocap) @ 1 ml/ l or Wettable sulpher @ 2g/l at 10-12 days interval.

**Fusarium Wilt** (*Fusarium oxysporum* f.sp. *pisi*)**:** The symptom of this disease is more pronounced in 3- 4 weeks old pea plants. The leaves may also turn yellow and drop off prematurely Wilting and drooping of the plants followed by sudden death. When the diseased stem is cut, there is a dark brown, discoloured band around the vascular system. Infection occurs directly through the root hairs. The fungus persists in the soil for an infinite amount of time. Infestation may be reduced by follow the crop rotation. Treating seeds with Carbendazim (2g per kg of seed) protects seed lings during the initial stages of growth. Soil drenching with copper oxychloride 0.25%. Spraying the crop with Bavistin (0.1%) also helps to control wilt.

**Physiological Disorders Frost damage**:
Pods can suffer from frost damage, which often occurs when the temperature drops below 0°C for an extended length of time. Frost damage can be lessened using sprinkler watering.

**Harvesting and Yield of Seeds**
Approximately 90% of the plant's pods mature and dry up before the entire plant is plucked and collected on the threshing floor. After around a week, the seeds are threshed and winnowed out of the pods. Drying is required to maintain the seeds at the necessary levels of 8% for standard packaging and 6% for vapour proof packaging because seeds frequently have a higher moisture content during this time. If the seeds are stored as recommended, they will remain viable for two years. Four to ten quintals of pea seeds can be produced from an acre of seed crop, depending on the cultivars.

**Post-Harvest Management**
The green pods should be handled carefully and kept in perforated boxes or gunny bags to avoid pod damage from rubbing or weight strain. When green pods are stored properly at low temperatures (0°C) and high relative humidity levels (90–95%), the metabolic breakdown is stopped, extending the green pea's shelf life by two to three weeks. The pods are frozen at -10°C. They can be stored at about 20°C for four to five days. To maintain their excellent freshness, pods should be stored in perforated polythene bags.

**Conclusion**
Garden pea farming is critical to global agriculture, nutrition, and economics. Its capacity to respond to a wide range of climatic conditions, as well as its significance in sustainable farming practices, make it an important crop for both farmers and consumers. Growers can obtain optimal yields and

high-quality food by selecting the right varieties, preparing the soil properly, and following best agronomic techniques. The use of contemporary technology, such as precision farming and pest-resistant cultivars, boosts yield while reducing environmental effect. Furthermore, the garden pea's ability to fix atmospheric nitrogen helps to increase soil fertility, making it a good choice for crop rotation systems. As global demand for plant-based proteins develops, garden peas have significant potential to meet these demands while also supporting environmental sustainability. Continuous research and innovation in growing strategies will be required to meet problems such as climatic variability, pest pressures, and market demands, ensuring that the garden pea remains a cornerstone of sustainable agriculture and a key food resource.

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# GENETICS OF AFLATOXIN: A HIDDEN TOXIN IN THE FOOD COURT ACROSS THE GLOBE

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**Abstract**

Aflatoxins are secondary metabolites produced by the soilborne fungus *Aspergillus flavus* and related species, which infect various crops, including groundnut and maize. Consuming contaminated produce poses serious health risks to humans and livestock and leads to significant economic losses for farmers. Over the past three decades, substantial research has focused on understanding the genetic behaviour, molecular mechanisms, and biology of host-pathogen interactions related to aflatoxin contamination. Various omics approaches have enhanced our knowledge of resistance mechanisms and the pathways involved in these interactions, primarily in groundnut and maize. This study summarizes recent advancements in the molecular mechanisms underlying host-pathogen interactions during aflatoxin contamination in these crops.

**Introduction**

Aflatoxins are secondary metabolites produced by various species in the *Aspergillus flavus*, and they are teratogenic, carcinogenic, and immunosuppressive (Frisvad et al., 2019). The primary species that produces aflatoxins is *A. flavus*; however, A. parasiticus, A. nomius, and other species can also be significant contributors to contamination in certain regions and years (Kachapulula et al., 2017). These fungi that produce aflatoxins can contaminate a variety of agricultural products, including groundnuts, maize, cottonseed, wheat, rice, tree nuts, and chili peppers. Aflatoxin persists in food and feed even after crops are cooked or dried due to its stability against heat and freezing. There are four main types of aflatoxins: AFB1, AFB2, AFG1, and AFG2, which can be identified by their distinctive blue and green fluorescence under UV light and their migration rates. AFB1, the most potent and toxic variant, is linked to hepatocellular carcinoma. Consumption of contaminated products can lead to both chronic and acute health effects, potentially resulting in fatalities (Sarma et al., 2017). Despite being the world's second-largest producer of groundnuts, India exports only 800,000 tons annually, primarily due to aflatoxin contamination (Suneja, 2019). Aflatoxin contamination is a frequent issue in semi-arid and arid regions of the United States, as well as in tropical and subtropical areas of Asia and Africa. In these affected regions, it is crucial to implement measures to mitigate contamination in order to safeguard consumer health, enhance crop competitiveness, and maximize agricultural potential to ensure food and nutritional security. Implementing genetic resistance in new crop varieties, along with effective agricultural practices, may offer a lasting solution to the aflatoxin issue. It is essential to investigate and utilize all available resistance strategies to control aflatoxin accumulation in the field, complemented by best practices throughout the entire value chain. In groundnuts, three distinct resistance mechanisms have been identified: in vitro seed colonization (IVSC), pre-harvest aflatoxin contamination (PAC), and aflatoxin production (AP), each inherited independently (Nigam et al., 2009). To achieve reliable genetic resistance against *A. flavus* infection, it is important to assess and combine all three mechanisms to ensure effective protection during field growth, harvesting, and storage.

**Factors influencing toxigenicity and aflatoxin contamination**

Various biotic factors, including fungal virulence, host susceptibility, insect damage, and abiotic factors such as soil moisture, temperature, high humidity, and mechanical damage during inter-cultivation practices, significantly affect the invasion of *A. flavus* and the accumulation of aflatoxin in groundnuts. In maize, hot and dry conditions (temperatures above 32°C and relative humidity above 70%), along with drought and damage to the kernel seed coat, increase the risk of aflatoxin contamination. High moisture levels in grain can lead to increased post-harvest mold growth and aflatoxin contamination. Therefore, properly drying grains after harvest to 7% moisture for groundnuts and 12% for maize is essential to prevent fungal growth (Liang et al., 2009). Temperature also plays a crucial role, as *A. flavus* thrives in a wide range of temperatures from 10 to 40°C, with the optimal range for aflatoxin production being 25–30°C. Storage conditions significantly impact aflatoxin levels in crops; To combat *A. flavus* infestation and aflatoxin contamination during storage, Purdue Improved Crop Storage (PICS) bags, which utilize hermetic storage principles, have been effectively employed. Therefore, an integrated management approach addressing aflatoxin contamination during pre-harvest, post-harvest, and storage is essential to minimize both contamination and exposure.

**Genetics of resistance mechanisms**

The mechanisms behind resistance to infection and reduced aflatoxin production (AP) are primarily quantitative in nature. In groundnuts, these mechanisms include resistance to pod wall infection, prevention of seed invasion and colonization of the seed coat, and resistance to aflatoxin production in the cotyledons. For aflatoxin producers to infect groundnuts, they must first penetrate the pod wall and then the seed coat to access the cotyledons, where they obtain nutrients and produce aflatoxin. Resistance to pod infection is largely attributed to the structural characteristics of the pod shell, while seed invasion and colonization resistance are mainly physical, linked to factors such as seed coat thickness, the density of palisade cell layers, and the presence of wax layers (Upadhyaya et al., 2002).

In maize, resistance mechanisms include effective husk coverage, the presence of proteins that inhibit fungal growth, and layers of wax and cutin. Maize that maintains kernel integrity and has a viable embryo typically shows lower levels of aflatoxin accumulation. Generation mean analysis in maize has indicated that both additive and dominant gene actions play significant roles in resistance to aflatoxin production (AP). Researchers employed diallel mating designs to investigate the inheritance patterns associated with resistance to Aspergillus ear rot and aflatoxin accumulation. These studies found that general combining ability had a more substantial impact on aflatoxin resistance in maize compared to specific combining ability, highlighting the greater importance of additive gene effects over dominant gene effects.

**Molecular basis of aflatoxin resistance mechanisms**

**Identification of Resistance-Associated Proteins**

Proteomics approaches have revealed numerous plant proteins that play crucial roles in host-pathogen interactions and in regulating resistance to fungal invasion and toxin production in both groundnut and maize. For example, a 2D-based proteomics study in groundnut identified several pathways and proteins, including resistance-associated proteins (RAPs), linked to pre-harvest aflatoxin resistance under drought stress conditions. This study underscored the importance of proteins such as iso Ara-h3, oxalate oxidase, PII protein, trypsin inhibitor, SAP domain-containing protein, CDK1, L-ascorbate peroxidase, RIO kinase, and heat shock proteins in mitigating aflatoxin accumulation during the pre-harvest phase. Subsequently, Wang et al. (2012) identified additional RAPs in groundnut that were pivotal in regulating pathways related to immune signaling, PAMP perception, cell wall responses, and detoxification. Furthermore, research on the effects of H2O2-derived oxidative stress on *A. flavus* isolates uncovered a subset of genes that influence fungal pathogenicity, mycelial development, and the management of reactive oxygen species (ROS) production.

**Identification of Candidate Genes**

To investigate the molecular mechanisms of host-mediated resistance, a study was conducted comparing Aspergillus-resistant (GT-C20) and susceptible (Tifrunner) groundnut genotypes, resulting in the identification of 52 highly expressed and 126 moderately expressed genes (Guo et al., 2011). This research highlighted several significant genes, including lipoxygenase, lea-protein 2, proline-rich protein, and cupin/oxalate oxidase, in response to *A. flavus* infection. Additionally, some studies have proposed that the lipoxygenase (LOX) pathway may be involved in the production of jasmonic acid, which serves important regulatory and defense-related functions in plants.

**Metabolomics under *A. flavus* infection and aflatoxin resistance**

To investigate the mechanisms of aflatoxin resistance at the metabolite level, several metabolome studies have been conducted in maize in response to *A. flavus* infection. For example, the metabolome profile during *A. flavus* infection revealed a significant increase in the expression of polyamine (PA) biosynthesis genes in resistant maize lines TZAR102 and MI82 compared to the susceptible line SC212. The elevated levels of spermidine (Spd), spermine (Spm), and diamine putrescine (Put), along with their increased breakdown in the resistant lines, suggest that polyamines play a critical role in conferring resistance to *A. flavus*. Additionally, higher concentrations of amino acids such as glutamate (Glu), glutamine (Gln), and γ-aminobutyric acid in the susceptible maize line SC212 indicate that these amino acids may promote *A. flavus* infection. In a related study, metabolites were analyzed at the R3 (milk), R4 (dough), and R5 (dent) stages of cob development following *A. flavus* infection (at four dosage levels). The findings demonstrated that grain colonization decreased as kernel maturity progressed, with approximately 100%, 60%, and 30% colonization observed in milk, dough, and dent stage kernels, respectively.

**Conclusion**

Various cultural and biological methods have been proposed to manage aflatoxin contamination in groundnut and maize. Developing resistant varieties, hybrids, or transgenic crops remains a significant challenge. Recent omics studies have generated valuable genetic and genomic resources, enhancing our understanding of Aspergillus infection, aflatoxin reduction mechanisms, host-pathogen interactions, fungal toxigenicity, and aflatoxin biosynthesis inhibitors. Promising genomics and transgenic strategies have shown complementary benefits by integrating genes, peptides, antifungal proteins, and silencing key genes to improve resistance against Aspergillus growth and aflatoxin production in susceptible varieties.

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# RENEWABLE ENERGY – AN OVERVIEW

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**Abstract**

Renewable energy is one of the environmentally friendly sources of energy. In present energy scenario harnessing of renewable potential in effective manner is becoming need of the era, which can provide sustainable power supply as well as mitigate the negative environmental impact due to fossil fuel. Energy is the major source for the economic development of any country. In case of the developing country like India, shortage of electricity work as a barrier for development. In recent years, India's energy consumption has been increasing at a relatively fast rate due to population growth and economic development. Rapid growth of the Indian economy places heavy demand of electric power. Equality between economic progress and environmental sustainability is essential for a developing country like India. In order to achieve stable sustainable energy in the long-run, significant progress in renewable energy sectors is needed. Favorably, due to India's geographic location, the country is blessed with abundant renewable energy resources, which has not yet been exploited completely. So the central and state governments of the country have framed various policies and are providing subsidies.

**Keywords**: Renewable energy, sustainable energy, fossil fuels, electricity.

**Introduction**: India is the third largest energy producer in the world after the China, united state and India. the per capita total electricity consumption in India was 917.2 kWh. Electricity consumption in India is expected to rise to around 2280 BkWh by 2021–22 and around 4500 BkWh by 2031–32. India's energy consumption has been increasing comparatively fast rate due to increase in population and living standard as well. Current centralized energy planning of India is mainly dependent on thermal power plant for energy need and its percentage share is near about 70% of total installed capacity of power plant This over dependency creates pressure on fossil fuel. The improvement of renewable energy technologies will assist sustainable development and provide a solution to several energy related environmental problems. In this sense, optimization algorithms constitute a suitable tool for solving complex problems in the field of renewable energy systems. most popular form of energy being used nowadays is electricity. Modern electric power system is an interconnected network comprising of power generation, transmission, distribution and utilization.

**Renewable energy:** Renewable energy is derived from natural processes that are replenished constantly. India is blessed with a variety of renewable energy sources, the main ones being biomass, biogas, sun, wind, geothermal, tidal and small hydro power.

- Wind energy
- Solar energy

- Geothermal energy
- Small hydro energy
- Wave energy
- Tidal energy
- Biomass energy

**Wind energy**: wind power installed capacity, India is ranked 5th in the World. Today India is a major player in the global wind energy market. Tamil Nadu, Maharashtra, Karnataka, Rajasthan, Gujarat are the key states which have been focusing on wind energy development in India. The complete dependence on climatic conditions is major obstacle in this case.

**Solar energy:** solar energy potential is the highest in the country. The equivalent energy potential is about 6000 million GWh of energy per year. India lies in the sunny regions of the world. Most parts of India receive 4– 7 kW h of solar radiation per square meter per day with 250–300 sunny days in a year. The National Solar Mission targeting 20,000 MW grid solar Power, 2000 MW of off-grid capacity including 20 million solar lighting systems and 20 million square meters solar thermal collector area by 2022 is under implementation.

**Geothermal energy:** Geothermal energy comes from the natural heat of the Earth primarily due to the decay of the naturally radioactive isotopes of uranium, thorium and potassium. Around 6.5 per cent of electricity generation in the world would be done with the help of geothermal energy and India would have to play a bigger role in the coming years in this direction.

**Small hydro energy:** Hydro projects in India, which are under 25 MW in capacity, are classified as “small hydropower” and considered as a “renewable” energy source. The sector has been growing rapidly for the last decade. the oldest renewable energy technology used to generate electricity in India. The current total installed capacity of small hydropower plants is 3803.68 MW. The energy of running water has been exploited for many years. Hydro projects can be unreliable during prolonged droughts and dry seasons when rivers dry up or reduce in volume.

**Wave energy:** Waves are formed by wind blowing over the surface of ocean. Wave energy is a renewable energy whereby we capture the energy that is being generated naturally by waves and can transmit their energy over long distances with little degradation.

**Tidal energy**: Energy available in water because of the rise and fall of water level during high and low tides. Tidal energy technologies harvest energy from the seas. when considering the sea as a resource. In India, Gulf of Kutch and Gulf of Cambayin Gujarat and delta of Ganga in Sunderbans, Parganas district, West Bengal are potential sites for generating tidal power.

**Biomass energy**: Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant- based materials which are specifically called ligno-cellulosic bio- mass [36]. Biomass include wood, logging wastes and sawdust, animal dung and vegetable matter consisting of leave, crop residues and agricultural waste.

**Currrent energy policies in india:** Government incentives and national policies existed to encourage renewable power generation in India, until 1990, there was no significant participation from the private sector. The participation from the private sector started effectively after the declaration of the “private power policy” in 1991 therefore the ultimate objective of the renewable energy policy framework is to significantly increase the share of renewable energy source in India's energy mix.

Different energy policies announced by Indian government to enhance power generation from conventional and non-conventional sources especially focusing on renewable power generation are given below:

1. National electricity policy 2005.
2. Electricity Act 2003.
3. Tariff policy 2006.
4. National rural electrification policies 2006.
5. National action plan on climate change 2008.

**National electricity policy 2005**: The National Electricity Policy was introduced in 2005 to access the electricity, availability of power demand, to overcome the energy and peaking shortages, to supply reliable quality power at reasonable rates, to increase the per capita availability of electricity by 1000 units, and also to make the electricity sector commercially viable to take care of consumers' interests.

**Electricity Act 2003:** In 2003, the Electricity Act came into existence, originating from three of the earlier acts that regulated the electricity sector, viz., the Indian Electricity Act (1910), the Electricity (Supply) Act (1948) and the Electricity Regulatory Commissions Act (1998). The electricity act contains different section which focuses toward rural electrification, transmission and distribution, the promotion of cogeneration and generation of electricity from renewable sources of energy by providing, suitable measures for connectivity with the grid and sale of electricity to any person.

**Tariff policy 2006**: The Tariff Policy announced in January 2006 to fix minimum percentage for purchasing of energy considering the availability of resources, procurement by distribution companies at preferential tariffs etc.

**National rural electrification policies 2006**: The National Rural Electrification Policies were established in 2006 to come up with the objectives of providing access to electricity (reliable quality power supply) to all households by the year 2009 and to provide energy to all villages either through grid connected or through off-grid solutions, such as stand-alone systems.

**National action plan on climate change 2008**: On June 30, 2008, Prime Minister Manmohan Singh released India's first National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs addressing climate mitigation and adaptation. The NAPCC includes eight missions of which the major two energy related missions are the Jawaharlal Nehru National Solar Mission (JNNSM) and the National Mission for Enhanced Energy Efficiency (NMEEE). The objective of JNNSM to make solar energy competitive with fossil based energy. The objectives of the NMEEE include demand management with a target to save at least 10 GW of energy by the end of 2012.

**Conclusion**

The power sector and scarcity of fossils fuel boost the efforts for development and pro- motion of renewable energy sources. Renewable energy will increasingly play an important role in the overall energy mix in the country and will continue to contribute towards addressing the present and future power supply deficits as well as enhancing the energy access in remote areas. These include up to 14% by replacing coal with renewable energy. India has sufficient potential of renewable energy but combination of the right technology and correct human behavior is needed because every technology have their own limitation. Enhancement of R&D activity, innovation of new technology, benchmarking etc is also required for efficiency improvement, More and more government support through Subsidy and support to the local entrepreneurs, tax exemption, feed-in tariffs (FITs), green certificate (GC), production tax credit (PTC), investment tax credit (ITC), soft loan etc. are also highly recommended for promoting renewable energy technologies.

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# RENEWABLE ENERGY FOR A CLEAN ENVIRONMENT AND A SUSTAINABLE FUTURE OF INDIA

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India, with a population exceeding 1.4 billion, faces the dual challenge of ensuring energy security while addressing growing environmental concerns stemming from its continued reliance on fossil fuels. The country's energy consumption is projected to rise significantly in the coming decades, driven by population growth, urbanization, and industrialization. Therefore, adopting renewable energy is crucial not only to meet the increasing demand for energy but also to reduce environmental degradation, combat climate change, and pave the way for a sustainable and green future.

**Environmental Benefits of Renewable Energy**

India faces critical environmental challenges, particularly air pollution, which significantly contributes to respiratory diseases and premature deaths. The country's dependence on coal and other fossil fuels for electricity generation results in high levels of greenhouse gas emissions, especially carbon dioxide ($CO_2$). These emissions have both local and global impacts, worsening air quality and accelerating climate change.

**a) Reduction in Greenhouse Gas Emissions:**

Renewable energy sources such as solar, wind, hydro, and biomass produce little to no emissions during operation. By replacing fossil fuels with clean energy, India can substantially cut its carbon emissions and reduce its contribution to global warming.

**b) Improvement in Air Quality:**
Fossil fuel-based power plants are among the largest contributors to air pollution, emitting particulate matter, sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and other pollutants. Transitioning to renewables mitigates these harmful effects, leading to cleaner air and improved public health, particularly in urban areas.

**c) Reduction in Water Consumption:**
Thermal power plants use large quantities of water for cooling, straining local water resources. Renewable energy systems, especially solar and wind, require minimal water for operation, reducing water stress in regions facing scarcity.

**Renewable Energy as a Sustainable Energy Supply**
India's growing energy demand is currently met primarily by non-renewable sources such as coal, oil, and natural gas. These finite resources contribute to environmental degradation, including deforestation and habitat loss. Additionally, India's dependence on fossil fuel imports poses risks to energy security due to price volatility and geopolitical tensions.

**a) Abundant and Clean Energy Resources:**
India has vast renewable energy potential, particularly in solar and wind. With abundant sunlight throughout the year and extensive wind resources along its coastline, India is well-positioned to harness these clean energy sources. The country also has significant biomass and hydropower resources.

**b) Decentralized Energy Generation:**
Renewable energy systems, such as rooftop solar panels, can be deployed locally, reducing dependence on centralized power plants and transmission lines. Decentralization minimizes energy loss during transmission and enhances energy security in remote or rural areas.

**c) Energy Independence:**
Harnessing domestic renewable resources allows India to reduce reliance on imported energy, improving energy security and protecting against global fuel price fluctuations and geopolitical risks.

**Economic Growth and Employment Opportunities**
Transitioning to renewable energy not only benefits the environment but also drives economic growth by creating new industries, fostering innovation, and generating employment.

**a) Job Creation:**
The renewable energy sector is labor-intensive, creating jobs in manufacturing, installation, maintenance, and operations. Solar panel installation, wind turbine maintenance, and the production of clean energy components require a skilled workforce. India's renewable energy sector is projected to generate millions of new jobs in the coming decades.

**b) Attracting Investments:**
India's clean energy policies have made the sector attractive to domestic and international investors. Solar and wind projects have already drawn significant investment, supported by government incentives and subsidies.

**c) Economic Stability and Local Development:**
Developing renewable energy projects in rural areas generates local employment opportunities and drives regional economic development. Infrastructure such as electric vehicles and battery storage solutions further contributes to economic diversification.

**Improved Energy Access in Rural and Remote Areas**

Access to reliable electricity remains a challenge for millions in rural and remote parts of India. Many of these areas rely on traditional fuels like firewood and kerosene, which are detrimental to health and the environment.

**a) Off-Grid Solutions:**

Solar home systems, solar mini-grids, and wind power offer cost-effective, low-maintenance solutions for rural electrification, meeting the energy needs of local communities.

**b) Improved Living Standards:**

Reliable electricity improves living standards by powering schools, healthcare facilities, water pumps, and small businesses, reducing dependence on harmful traditional fuels.

**Technological Innovation and Energy Storage Solutions**

India's renewable energy journey is fostering advancements in energy storage, smart grids, and efficiency.

**a) Energy Storage:**

Technologies like lithium-ion batteries enable the storage of excess energy for use during high demand or low generation periods, ensuring a stable energy supply.

**b) Smart Grids:**

Modernizing the grid infrastructure is essential for integrating renewable energy. Smart grids enhance energy flow management, reduce losses, and stabilize the system.

**c) Innovation in Renewable Technologies:**

Research into advanced solar panels, offshore wind farms, and bioenergy solutions is reducing costs and improving efficiency.

**India's Renewable Energy Ambitions and Policy Support**

India has set ambitious targets under the Paris Agreement, aiming for 500 GW of non-fossil fuel energy capacity by 2030.

**a) 2030 Renewable Energy Target:**

India plans to achieve 500 GW of installed capacity from non-fossil fuel sources, with significant contributions from solar, wind, and biomass.

**b) National Action Plan on Climate Change (NAPCC):**

The NAPCC includes missions promoting renewable energy development and efficiency. Policies like the Solar Park Scheme and National Biofuels Policy support these goals.

**c) Favourable Government Policies:**

Incentives such as Renewable Energy Certificates (RECs) and Power Purchase Agreements (PPAs) encourage private sector participation.

**Challenges to Overcome**

Despite progress, several challenges remain:

- **Grid Integration:** Significant investment in smart grids and energy storage is needed.
- **Financing:** High upfront costs make funding large projects challenging.
- **Policy Consistency:** Stable and long-term policies are critical for investor confidence.

- **Land Acquisition:** Large-scale projects require extensive land, which can lead to environmental and social concerns.

**Conclusion**

Renewable energy is key to shaping India's clean, sustainable, and resilient energy future. By reducing reliance on fossil fuels, India can enhance energy security, foster economic opportunities, and contribute to global climate goals. Overcoming challenges through collaboration among government, industry, and civil society will be key to realizing this vision, creating a cleaner and more sustainable future for generations to come.

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# CHINA ASTER FLOWER FARMING HIGH-PROFIT FARMING

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**Introduction**

The China aster (*Callistephus chinensis* L. Nees) was introduced from China in early Eighteenth Century. It is an important annual flower crop grown commercially in many parts of the world for loose flower production. Its position is next to chrysanthemum and Svariations. Today it is one of the most valuable garden flowers, the different types of colours include pure white, many shades of pink, primrose, pale blue, purple and scarlet are there. The present-day aster has been developed from a single form of wild species, *C. chinensis*, a plant native to China. China aster is being popularizing rapidly in India due to easy cultural practices. Some major growing states are Arunachal Pradesh, Karnataka, Tamil Nadu.

**Use:** China aster is excellent as a loose flower. It is widely cultivated in many parts of country especially south Indian region. It is grown for bedding and potted plants, offering to the Gods etc. The dwarf Pompon and Lilliput type can be grown in window boxes and in mixed borders. These flowers come in a variety of colours and could make for a great addition to a traditional flower garden or container garden.

**Varieties:** Some important cultivars released from IIHR.

| **Arka Nirali, Arka Nidbica** | **Mutant variety** |
|---|---|
| **Arka Poornima** | Flowers are powderpuff type, pure white in colour, disc tubular; suitable for garland, floral decoration and cut flower |
| **Arka Adhya** | Pink-coloured, early flowering, spreading growth habit; for bedding and loose flower |

| **Arka Nirali, Arka Nidbica** | **Mutant variety** |
|---|---|
| **Arka Archna** | White coloured early flowering, spreading growth habit; for bedding and loose flower, high yielding |
| **Arka Shashank** | Flowers are powderpuff with tubular ray florets, creamy white in colour; suitable for garland, floral decoration and cut flower |
| **Arka Kamini** | Flowers are semi-double type, deep pink in colour; suitable for garland, floral decoration and cut flower |

**Other important varieties of China aster**: Phulla ganesh white, Phulla ganesh pink, Poornima, Violet cushion, Giant of California (late flowering).

**Climate:** Generally, China aster is winter season crop, they require shady area for proper growth. For germination $28^0$C temperature with dark light, and 20-$22^0$C temperature for growth and development with 70-85% relative humidity it requires. It grows best in sunny situation.

**Soil:** For proper growth and development China aster require well drained, rich of organic matter, high porous, loamy soil with 6.8 – 7.0 pH are most suitable. High calcium and heavy soil are not preferred for China aster production because they are highly susceptible of them.

**Propagation:** Propagation is usually done by seed. Seed are raised in seed pans or some time directly in the bed. Seed are shown in the month of August to October and even earlier in June or July where rainfall is prevailing in summer. Water should be given very carefully and it is advisable not to water unless the seed pans become fairly dry. Seed should be thinly covered with soil. When seedling is in 4-leafed stage they should be transplanted to 7.5 cm pot, or in bed.

**Seed rate:** For one hector China aster production 2.5 - 3 kg seeds are required.

**Spacing:** 30 x 30 cm is ideal for proper development.

**Weeding:** Weeding is important practices is done in the China aster field if weeding is not done in proper time, then they can affect the flower quality. Initially weeds are removed manually with the help of khurpi and spade. If weeds are affect high then we should spray chloropropane @ 9-25 kg/ha, 4-6 weeks day after transplanting.

**Nutrient management:** At the time of bed preparation sufficient organic manure, about 4-5 kg per square meter added to the soil. Then 180 kg Nitrogen, 60 kg Phosphorus, 60 kg Potash are require for one hector China aster crop. Half does of nitrogen and full does of phosphorus and potash are incorporated in field at the time of field preparation, remaining half does of nitrogen (90 kg) are provide after 40 days of transplanting. Some micro nutrient also provide to the plant like Zink, Boron, Copper, and Manganese they help in enhance the quality of flower.

**Irrigation :** For higher yield irrigation is necessary .in summer season 2-3 time and in winter ones in a week irrigation should be done.in rainy season irrigation requirement is depend on the rain, if rain is not occurs from long time then water should be provided.

**Pests & Diseases:** The most common diseases to impact China asters are aster yellows, aster wilt, and root rot.

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**Aster fusarium wilt** is a soil-borne fungal disease that causes the leaves to brown and wither. If timely we not control the infection then whole plant will be died.
**Control:** it is best to remove any infected plants (never burying or using as compost) and pick wilt-resistant cultivars going forward, or control by chemical fungicide mercuric chloride @0.1% solution.

**Aster stem and root rot is** another nasty soil-borne fungal disease that attacks the roots, stems and lower leaves
**Control :** Prevent the problem by planting in a well-drained site and avoiding overwatering. If rot sets in, planting new flowers in a different site is best. Also, control by chemical name Zeneb or Indofil M- 49 @ 1.2% solution.

**Yellow chrysanthemum mosaic virus** is a viral disease transmitted by leaf hopper. They cause serious injury to the plant leaf and also reduce the quality of the flower.
**Control :** There is no cure for virus-infected plants. Remove and distroy them. To control the insect that transmit these viruses, remove weeds that may harbor the viruses, Wash tools used around the infected plant.

**Insect control :** Generally aphid and red spider mite are the major insect occur in the China aster flower.

**Aphid :** aphid are brown to black they may feed by piercing plant tissue and sucking plant sap. they prefer feeding on new growth in such area as shoots, the undersides of leaves, bud and flower. There feeding can result in distorted growth, stunting, and sometimes death of the entire plant.

**Control :** They can be control by Endosulfon @ 0.5 solution or control through neem or pongemia oil @ 2% solution.

**Red spider mite :** mite are not insect but closely related to spider. Thay are small and have piercing mouthpart with which they puncture plant tissue and suck plant sap. Spider mite will be initially on the lower surface of leaf.

**Control :** for disease control first we should remove the affected portion of plant. And spray of Ethion 5ml/10 litter of water at 15 days interval.

**Some cultural practices involve in China aster**
**Pinching :** Pinching is done after one month of transplanting it is done to divert the energy from the apical portion to the lateral branches, to increase the lateral branches and increase the flower yield.

Spray plant growth regulators like GA3 @200-300 ppm to increase flower per plant and increase bloom size per plant. To regulate the flower bloom, we can spray maleic hydrazide, this practice is done so flowers can be obtained according to the willingness of the farmer.

**Earthing up :** Earthing up is done after 45 to 55 days after transplanting, through earthing up plants are supported by soil after gaining their proper height.

**Yield :** 12 tonne/ha. It depends on several factors like weather condition, irrigation, nutrient application etc.

**Post-Harvest management.**

- **Handling:** Immediately place harvested flowers in water to preserve freshness. If they are to be stored or transported, ensure that they are kept cool, preferably in a refrigerated environment.
- **Storage:** Store cut flowers in a cool, dark place. Use floral preservatives (sugar and citric acid) to extend vase life.

**Economic value :** China aster gives higher net return profit. Farmers can get money according to the demand such as at festivals or at marriage time which provides higher economic value. Average rate of China aster of Rs. 60 per kg but in festival season the value is increases at Rs. 300-350 per kg.

**Conclusion** : The production of China asters involves careful planning SDS. The key factors influencing successful production include optimal growing conditions, proper care during the growing phase, pest and disease management, and harvesting at the right time. With the right techniques, China asters can thrive and provide beautiful flowers for ornamental use, cut flower production, and landscaping. By maintaining good agricultural practices and ensuring quality inputs, growers can achieve high-quality blooms and a profitable harvest.

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# COMPARATIVE ANALYSIS OF MOSQUITO INSECTICIDE RESISTANCE BIOASSAYS: METHODS, ADVANTAGES AND APPLICATIONS

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**Abstract**
This article evaluates various methods for assessing insecticidal resistance in mosquitoes. The Cone method, WHO Wire Ball test, WHO Susceptibility Test, CDC Bottle Assay, and MCD Bottle Bioassay are described, each with different exposure procedures and mosquito monitoring techniques. Key differences include exposure duration, mortality recording, and the use of synergists. The CDC and MCD methods stand out for their cost-effectiveness and simplicity, while the WHO tests are more standardized but costlier. The article highlights advantages and disadvantages of each method for resistance monitoring, offering insights into their practical applications for vector control.

## Introduction

### WHO cone test

This method is used to find the insecticidal resistance activities in mosquitoes. Here, the insecticide added net is taken and a cone-like substance is placed above the net taken, and there is need of introduction of mosquitoes on the top side of the cone after all this process is done it is closed with the cotton ball.

**Methodology:** For this assay test, 2-5 days old non-blood fed susceptible female mosquitoes were taken and allowed them inside in the cone for the exposure period of 3 minutes. After the exposure, we transfer these mosquitoes into the 150 ml plastic cups which were provided with sucrose solution which mainly serves as food and maintain suitable environment for 24 hours at 27 ± 2°C and 80 ± 10% RH. Percent knockdown was noted down after 60 mins and after 24 hrs percent mortality can be recorded, (WHO, 2006).

Advanced insecticide resistance assays for mosquitoes

**WHO wire ball test:**

**Methodology:** Insecticide added net is wrapped around a wire frame of 15 x 15 x 15 cm. And netting around the frame, then leave a small sleeve in which the mosquitoes were introduced into the wire ball. As in the cone method here also allow the mosquitoes for an exposure period of 3 min and then transfer them to the holding cups. After 24 hrs mortality was recorded.

**WHO wire ball test**

**WHO Susceptibility Test**

In this assay test, the procedure will be same as in the cone and wire ball test is followed *i.e.*, introduce the 2 to 5 days old non-blood-fed susceptible female mosquitoes for the exposure period of 3 mins. But, here while releasing into the WHO exposure tube which was lined with a diagnostic dose of insecticide-impregnated filter paper. Knockdown was recorded every 5 mins for the period of 1 hr. After this period of time, transferring of mosquitoes into another tube with 10 per cent sugar solution at 27 ± 2˚C and 80 ± 10 RH for 24 hrs then the mortality was recorded.

**Advantages of WHO susceptibility test**

1. Knockdown of treated insects was easily measured.
2. Standard diagnostic doses or procedure were followed in the assay.

**Disadvantages**

1. There is no chance of use of synergist.
2. More cost of WHO kit when it is compared to other methods, (Owusu, *et al*., 2015).

**CDC Bottle Assay**

Brogdon and McAllister (1998), discovered the alternative method to the WHO susceptibility test which is the CDC bottle assay. This method was first developed under the Centre for Disease Control hence referred to as CDC. 250 ml of glass bottle was coated with 500 µl of insecticide mixture along with acetone. Later release 3 to 5 days old female mosquitoes into it. Knockdown was measured after 120 mins followed by the treated mosquitoes were transferred into the 30 ml plastic beaker with 10 per cent sugar solution. After 24 hrs mortality was noted.

Two synergists were selected and used firstly S.S.S tributylphosphorotrithioate (DEF) at the rate of (125 µg/bottle), which mainly acts as inhibitor of esterase activity and another one is piperonyl butoxide (PBO) at the rate of (400 µg/bottle) which acts as inhibitor of oxidase activity. For this assay test 125 mosquitoes were used. Mortality rate was recorded during the different time periods like, 0, 15, 30, 35, 40, 45, 60, 75, 90, 105 and 120 mins, (Aizoun, *et al*., 2013).

**Advantages**

a. Simple, fast and cost-effective method.
b. Use of synergist is only feasible here.

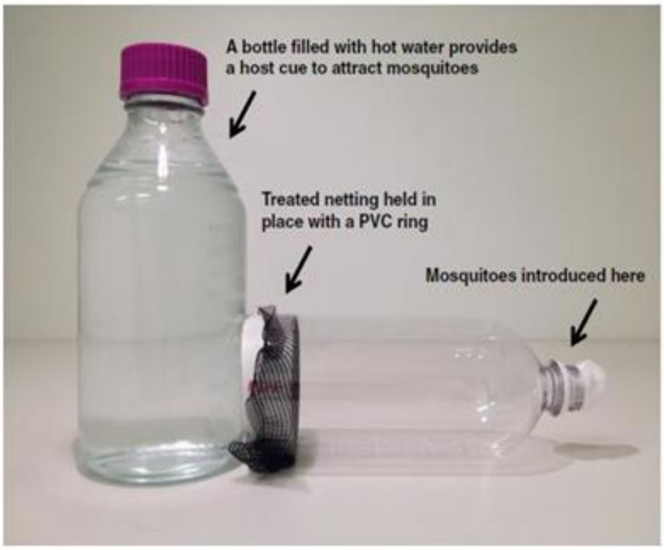
**Disadvantages**

a. Shelf life and re-use of the bottle is not well considered till now.
b. We need to coat insecticide for each and every time of bioassay.

**MCD bottle bioassay**

This method was developed under the Mosquito Contamination Project hence and it is named as MCD bottle assay.

**Methodology:** In this method, 1-liter plastic bottle is used and it is placed in a glass bottle with the bottom cut off and then fix insecticide added net along with a rubber band for support. Then this structure was attached to a glass bottle, which has used as cue for mosquitoes. *Anopheles stephensi* was used and allowed them exposure period of 3 mins. Exposure time is calculated from the time when mosquitoes are introduced into the bottle not the exact time when mosquitoes contact the Insecticide added net. After the exposure period, we want to transfer them into the paper cups with sugar solution as food source, and replace the food daily. Knockdown effect is measured after 1hr and mortality monitoring was extended up to the one-week post-exposure, (Sternberg, *et al*., 2014).




**MCD Bottle bioassay**

**Conclusion**

Each method provides valuable insights into insecticidal resistance but varies in terms of cost, simplicity and applicability. The WHO tests are more standardized but costly, while the CDC and MCD assays offer quicker and cheaper alternatives. The choice of method depends on research goals, resources and the need for precision in monitoring mosquito resistance for effective vector control strategies.

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# GENETIC DIVERSITY AND CONSERVATION STRATEGIES OF LARGE CARDAMOM IN SIKKIM

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## Introduction

*Amomum subulatum*, native to the sub- Himalayan tropical woods of wet deciduous and evergreen forests have significant medicinal benefits being frequently utilized in Ayurveda. This perennial plant belongs to Zingiberaceae family and thrives in shaded environments (30-50%) traditional agroforestry systems, particularly under the non-leguminous N-fixing tree *Alnus nepalensis* (about 70%) and 30% are under the mixed-tree agroforestry species. It flourishes at an an altitude of 1000-2000m with temperature range of 10 to 30ºC and uniformly distributed rainfall ranging from 3000-3500 mm per annum.

It has been traditionally used as an appetizer, a digestant also as an antispasmodic as recommended by Indian Ayurveda. Known for stimulating the heart, acting as an expectorant, and contributing to treatment of pulmonary tuberculosis, large cardamom has been valued for its diverse therapeutic properties. Additionally, it has found use in addressing issues such as loss of appetite, halitosis, dental and gum afflictions, inflammation of the eyes, and respiratory problems. The seeds have further extended their utility as components in mouthwashes, foods, beverages, perfumes, and medicines, known for their tonic effects on the heart and liver. Large cardamom has become a staple in flavoring agents, frequently incorporated into masalas and curry powders. In Gulf countries, it serves as an economical substitute for enhancing the flavor of tea.

*A. subulatum* is distinguished from *Elettaria cardamomum* by its larger, dark brown pods and a more specialized pollination system involving fewer pollinators. The practice of on-farm conservation aligns closely with preserving the agroecosystems where crops have naturally evolved, leveraging traditional farmer knowledge to guide cultivation and management strategies. North-East India, with its extensive co-evolution of large cardamom and the local human population, shows high intraspecific diversity, making it a promising region for on-farm conservation efforts. By integrating traditional knowledge with modern conservation strategies, we can support farmers in maintaining genetic diversity on their farms, ensuring the sustainability and resilience of large cardamom cultivation in the region.

## Status of Large Cardamom

India is the second largest producer and exporter (1000 MT capsules valued Rs. 12 crores) in the world after Nepal producing 35% of the world's total large cardamom production. India, formerly the most important producer, since 2000 has been the second worldwide, generating around 15,000 tonnes annually. At national level, Sikkim is the largest producer, contributing 85% of total production in the country. The agroforestry systems centered around large cardamom generate substantial revenue, with Sikkim alone contributing 40-50 crores. Darjeeling district in West Bengal also plays a crucial role, often referring to large cardamom as a "currency crop". India exported 665 tonnes of large cardamom in 2014-15 and collected revenue of ₹2,011.50 lakh in the international market. In India, major portion of the crop i.e. 1500-1800 MT is consumed domestically, and the rest is exported to other countries including Australia, Canada, Pakistan, South Africa, United Arab Emirates, the United Kingdom and the United States. Within India, the market channels for large cardamom involve farmers selling cured capsules through aggregators or, alternatively, through contractors or bidders in auction centers. This dynamic interplay of cultivation, trade, and global demand highlights the pivotal role large cardamom plays in India's agricultural landscape.

**Extent**

The total acreage in India is 30,000 ha with total production of 5,000 MT and the total productivity is 175 kg $ha^{-1}$. In India it is cultivated in Sikkim, the Darjeeling district of West Bengal, Arunachal Pradesh, Nagaland, and Uttarakhand. Since 2006, more than 60% of the plantations have become non-productive resulting in a tremendous decline in cultivated area. In the region of Sikkim, the initially recorded cardamom-yielding area experienced growth, reaching 22,714 hectares in 2003. However, a more recent report from Down to Earth highlights a decline to 17,735 hectares during the cultivation year of 2017-18. This trend signals a noteworthy shift in the landscape of large cardamom cultivation, prompting concerns about the sustainability and productivity of these plantations in the specified regions. Notably, the large cardamom industry has a considerable export network, with 50 registered exporters of spices located in the North East and a significantly larger contingent of 2,300 in the rest of India. This delineates the geographical distribution of export activity and underscores the regional significance of large cardamom cultivation in the country.

**Crop Cultivars and Varieties**

All the cultivars of large cardamom cultivated commercially belong to species, *A. subulatum* Roxburgh. About eight species are considered to be native of eastern sub Himalayan region out of 150 species occurring in the tropics viz., *A. subulatum* Roxb., *A. delbatum* Roxb., *A. aromaticum* Roxb., *A. linguiforme* Benth., *A. kingii* Roxb., *A. corynostachyum* Baker., *A. costatum* Benth *and A. plauciflorum* Baker. Popular cultivars such as Ramsey, Sawney, Varlange, Ramla, Seremna, Dzongu Golsey, and Bebo, along with sub-cultivars like Boklok, Tali, Jaker, and Belak, have been identified.

Two high yielding varieties ICRI SIKKIM 1 and ICRI SIKKIM 2 with yield potential 800 kg/ ha were developed in 2004 by the Indian Cardamom Research Institute, Tadong, East Sikkim, derived from the Sawney cultivar. Seremna, a location-specific cultivar developed by the Limboo tribes of Hee-Bermiok, West Sikkim, has demonstrated tolerance to pests and diseases, yielding between 300 to 450 kg $ha^{-1}$. Another disease-tolerant cultivar is Dzongu-golsai, developed by the Lepchas of Dzongu, North Sikkim. A total of 254 accessions based on high yielding lines and other specific characters are collected and Germplasm conservatory are established and maintained at Regional Research Station, Indian Cardamom Research Institute, Pangthang Research farm East Sikkim and Kabi research farm in North Sikkim.

**Crop Improvement**

*1. Acclimatization :* As large cardamom is a cross pollinated species and is replaced after few years it has greater acclimatization capacity.

*2. Flowering and pollination :* Large cardamom, is dioecious and bumble bees, specially *Bombus haemorrhoidalis* and *Bombus breticeps*, are major pollinators. Bumble bees are effective pollinators because of its compatible size with the flowers. The highest foraging activity of bumble bees is seen during 6–7 a.m during rain free condition. Anthesis and pollen release occurs early morning (3–4 a.m) whereas stigma receptivity starts an hour later and lasts for 24 hours, potentially extending to 36 hours during rain-free days.

*3. Genetical studies :* Genetic studies, such as those undertaken by Karibasappa *et al*., 1987, in five varieties of large cardamom (Sawney, Pink Golsey, Ramsey, Ramnag and Madhusey) have revealed high heritability coupled with high genetic advance for crucial characteristics. These include the length of mature tiller, panicles per clump, panicle weight, and capsule yield. Mature seed index, total soluble sugars (TSS) of seed mucilage and 1000 seed weight correlation studies by Karibasappa *et al*., 1989 showed positive association with oleoresin and negative association with cineol contents.

*4. Clonal selection :* Cultivation of the Barlang cultivar in high altitudes (1000-1800 msl) is marked by its high market value attributed to superior productivity and desirable traits, including a high ratio of mature tillers to productive spikes (1:3.6) and capsules characterized by bold size (with 50–80 seeds per capsule). The adoption of scientific cultivation practices in Sikkim, involves the establishment of disease-free quality sucker multiplication units and approximately 100 nurseries and clonal multiplication units, has empowered farmers to generate quality planting material.

*5. Propagation :* Vegetative buds for *in vitro* conservation and rhizome bits with buds for micropropagation are majorly used. The slow-growth method proves effective for in vitro conservation of large cardamom species. For the Ramsai, the recommended shot production protocol is 1 mg $L^{-1}$ BAP and 0.5 mg $L^{-1}$ IBA; however, for the Golsai and Sikkimae, the ideal shoot production levels are 0.5 mg $L^{-1}$ and 5 mg $L^{-1}$. At 0.5 mg $L^{-1}$ IBA and 0 mg $L^{-1}$ BAP. Propagation practices involve about 70% of cardamom-based agroforestry under nitrogen-fixing Himalayan alder, with remaining 30% under mixed-tree agroforestry species.

Nursery grown seedlings and suckers are used for plantation of large cardamom. Land preparation for new plantation starts with *weeding and cleaning* of the land during the month of April. Planting is done after the onset of monsoon showers (May-July) with enough soil moisture content. Pits with 30 x 30 x 30 cm of size and spacing of 1.5 to 1.8 m depending upon the type of cultivars to be grown are prepared. After weathering for fortnight, topsoil blended with manure along with the planting material are filled at the centre. Thereafter, the planting material could be staked and mulched with dried leaves.

**Reasons for Decline**

The production of large cardamom has declined in recent years. Main reasons for this is viral diseases like chirkey and phurkey, along with the impact of the *Colletotrichum gloeosporioides* causing leaf blight as reprted by Indian Cardamom Reserach Institute in 2011. Climate change also contributes as large cardamom needs a lot of moisture and water in soil but over time there is reduction in rainfall leading to drying of springs or streams in and around plantations, inadequate pollinator, shift in seasons, long dry spells during winter, frost or hail and extreme heat or cold. The soil moisture content has reduced which has allowed pathogens to flourish rapidly leading to emergence of diseases, pests, insects and inadequate pollination due to erratic rainfall during peak flowering season for cardamom (May–June), it causes flowers to fall and decay affecting the plant-pollinator relationship. The other major constraints are old farms, weak shade management, lack of disease free and quality planting material, using the same planting material year after year, spread of disease from alder tree preference of government job among youth, lack of research and development activities. To overcome this problem National Agricultural Innovation Project (NAIP), 2011, intervention has given emphasis on establishment of large cardamom sucker multiplication nursery for area expansion through gap filling and replantation.

**Need for Conservation**

Biodiversity plays an important role in sustainability, and cardamom based traditional agroforestry have a greater capacity for adaptability, ecological resilience and show more sustenance. It also acts as a habitat for pollinators and influences the ecological structure and functioning of ecosystem. Due to its shade loving nature, large cardamom is playing an important role in reducing deforestation and safeguarding forest cover, establishing itself as a premier landscape management strategy for biodiversity conservation. Hence it is regarded as the best landscape management for biodiversity conservation and excellent slope management, soil fertility maintenance and resilience to extreme conditions.

**Protocols**

The worldwide decline within the population of pollinators and the deterioration in the quality of habitats are of global concern particularly for sustaining the productivity of several crop species. There is an imperative need to document not only the absolute landrace diversity but also the relative abundance, spatial distribution, associated collective knowledge, incentives perceived by farmers, and threats to conservation. The development and implementation of people-centered policy that duly recognizes local knowledge, development of disease-free planting materials, training, subsidies, and improved irrigation facilities are central to improving cardamom farming practices and building socioeconomic and ecological resilience.

On-farm conservation may be an alternative way to conserve the species, especially those that grow in disturbed areas. The North east region of India can be proposed as a model for on-farm conservation of large cardamom germplasm, by considering practical and scientific problems while ensuring economic convenience for local farmers engaged in on-farm conservation. Identifying individuals actively involved in dynamic processes of conservation and genetic resource management is key.

**Benefits from On-Farm Conservation**

Farmers influence the alleles and genotype of a landrace for generations through their knowledge, preferences and practices, and contribute to shape the best trait under selection and management and their exposure to varying biotic and abiotic factors. Traditional practices are important to understand the spatial distribution of crop genetic diversity and its dynamics and to connect farmers and landraces within and across environment through seed flow and gene flow.

In response to changing environmental conditions the presence of genetic diversity in populations is fundamental for adaptive evolution, conserving these socio-biological systems is important because they contribute to retaining potentially useful but undetermined genetic variation, and to generating novel variation needed to maintain the capacity of crops to adapt to change.

**Schemes Being Implemented by the Spices Board in North-Eastern States**

1. Large Cardamom Development Scheme
   A subsidy of INR 17,500/- per hectare is provided, covering the expenses of planting materials. The subsidy is disbursed in two annual installments, with Rs. 15,000/- in the first year and Rs. 2,500/- in the second year.
2. Construction of Modified Bhatties for Large Cardamom Curing Houses
   For a curing house with a 200 kg capacity, a financial assistance of Rs. 5,000/- is allocated, while for a 400 kg capacity, the assistance is Rs. 9,000/-.
3. Extension Advisory Services
   Growers receive technical and extension support on the scientific aspects of cultivation and processing. This assistance is offered through personnel contact, field visits, group meetings, and the distribution of literature by technical officers of the board.
4. Recognition of Outstanding Large Cardamom Growers
   To foster healthy competition among growers, the board has introduced Large Cardamom Productivity Awards. The awards include:
   1st Prize: Rs. 25,000/-, Citation, and Certificate
   2nd Prize: Rs. 15,000/-, Citation, and Certificate

**New initiatives taken by the board:**

Spices Board of India offers a 3-month training program in Good Agricultural Practices (GAP) for unemployed rural youth with a background in 10+2 science. The training is available on a stipendiary or residential basis. In a bid to encourage continuous large cardamom production, the Spices Board has introduced the 'Special Purpose Fund for Replantation and Rejuvenation of Large Cardamom Plantations.' This scheme focuses on both re-plantation and rejuvenation efforts. Under the re-plantation scheme, small and marginal landholders are incentivized to revive neglected plantations using certified disease-free planting materials. Farmers with up to 4 hectares of land receive support of up to INR 12,500 (USD 225) per hectare, provided in two installments. For farmers with land holdings between 4–8 hectares, the support is INR 9,500 (USD 175) per hectare, granted upon the successful completion of the re-plantation program.

**Conclusion**

This review highlights the interconnectedness of genetic diversity, traditional practices, and environmental adaptation, emphasizing the need for holistic approaches to ensure the long-term resilience and prosperity of large cardamom cultivation in the region. The current trend of shifting to modernized agriculture and environmental degradation poses a serious threat, leading todecline in large cardamom diversity within traditional systems. concerted efforts towards on-farm conservation become imperative and requires collaborative approach involving farmers, policymakers, and researchers to safeguard genetic resources and uphold the cultural, economic, and ecological significance of large cardamom.

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# CHALLENGES FACED BY FARMERS IN USING SOCIAL MEDIA FOR AGRICULTURE

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## Abstract

Farmers increasingly rely on social media platforms to enhance agricultural practices, share knowledge, and connect with markets. However, several challenges hinder its effective use. Firstly, limited digital literacy among farmers, especially in rural areas, restricts their ability to navigate platforms and access relevant content. Secondly, unreliable internet connectivity in remote regions often disrupts access to real-time information and agricultural updates. Additionally, misinformation and the spread of inaccurate agricultural advice on social media can lead to poor decision-making. Furthermore, many farmers lack the resources to invest in smartphones and data plans, which are crucial for engaging with digital tools. Privacy concerns and the risk of data exploitation also discourage some farmers from fully utilizing social media. Addressing these barriers through improved digital education, infrastructure, and regulation is essential for empowering farmers and maximizing the potential of social media in agriculture.

**Keywords:** Farmers, Social media, Digital literacy, Agriculture, Misinformation

## Introduction

Social media has become an essential tool in modern agriculture, transforming how farmers, agribusinesses, and organizations communicate, share knowledge, and promote agricultural practices. With the increasing use of digital platforms such as Facebook, Twitter, Instagram, YouTube, and LinkedIn, social media offers a unique space for information exchange, marketing, and networking within the agricultural sector. In India, social media has become a vital tool for farmers, with 77% of farmers using WhatsApp for receiving farming advice, sharing knowledge, and staying informed about government schemes. Social media platforms like Facebook and Instagram are increasingly used for marketing, connecting farmers directly with consumers. 69% of Indian farmers are reported to use social media for accessing agricultural information, with a growing trend of digital adoption in rural areas. This digital shift helps farmers enhance their productivity, improve access to markets, and participate in online agricultural communities for knowledge sharing and support.

## Discussion

Social media in agriculture is transforming the way farmers, agribusinesses, and agricultural organizations communicate, share information, and promote products. Platforms like Facebook, Instagram, WhatsApp, Twitter, and YouTube have become essential tools for farmers and stakeholders to access real-time information, learn about new technologies, and engage with their communities.

**Key Roles of Social Media in Agriculture:**

1. **Information Sharing**: Social media provides a platform for farmers to share farming techniques, weather updates, and pest control methods. Online communities and groups facilitate knowledge exchange, helping farmers solve challenges and improve productivity.
2. **Market Access**: Farmers use social media to market their products, connect directly with consumers, and promote their businesses. Platforms like **Instagram** and **Facebook** allow farmers to showcase their products visually and engage with a wider audience, expanding their market reach.
3. **Networking and Collaboration**: Social media enables farmers to connect with peers, experts, and agribusinesses, fostering collaboration and networking. These connections help share resources, learn from industry leaders, and support each other in times of need.
4. **Advocacy and Policy Influence**: Social media serves as a powerful tool for advocacy, allowing farmers to raise awareness about key issues such as sustainability, climate change, and government policies. Organizations and individuals use social platforms to advocate for changes in agricultural practices or policies.
5. **Digital Tools for Development**: In countries like India, social media is used not only for communication but also for accessing agricultural development programs and government schemes, helping farmers improve their knowledge and practices.

**Challenges**

While social media offers many benefits to farmers, its use in agriculture also comes with several challenges:

1. **Digital Literacy**: Many farmers, especially in rural areas, may not have the necessary skills to effectively use social media platforms. Low levels of digital literacy can hinder their ability to access information, engage in online communities, or take advantage of online marketing opportunities.
2. **Internet Connectivity**: In many rural regions, poor internet connectivity or a lack of access to reliable networks can limit farmers' ability to fully utilize social media. Slow speeds and frequent outages may make it difficult to access timely information or engage in online transactions.
3. **Misinformation and Reliability of Sources**: The spread of misinformation on social media can be a major issue. Farmers may come across inaccurate or misleading agricultural advice, which could negatively impact their farming practices. It can be challenging for farmers to differentiate between credible sources and unreliable information.
4. **Privacy and Security Concerns**: Farmers may be wary of sharing personal or business information on social media platforms due to concerns over privacy and security. With the growing risk of data breaches or cyberattacks, some farmers may hesitate to engage online.
5. **Overload of Information**: While social media provides a wealth of information, the sheer volume of content can be overwhelming. Farmers may struggle to filter through the noise to find the most relevant and practical advice for their specific needs.
6. **Financial Constraints**: Many farmers face financial limitations that prevent them from investing in smartphones, data plans, or other technology required for effective use of social media. This can further exclude them from the benefits of online resources and marketing tools.

7. **Cultural Barriers**: In some regions, traditional farming communities may be resistant to adopting new technologies or digital tools, preferring established, offline methods. Cultural barriers to change can make the widespread adoption of social media in agriculture more difficult.
8. **Lack of Localized Content**: While global agricultural content is available online, much of it may not be tailored to the specific needs, languages, or farming practices of local communities. This can limit the effectiveness of social media for farmers in diverse regions with unique agricultural conditions.

**Recommendations**

To overcome the challenges farmers face in using social media for agriculture, several recommendations can be implemented to improve access, usability, and effectiveness. Here are key strategies:

**1. Digital Literacy Training:**

- **Recommendation**: Provide targeted digital literacy programs and training sessions for farmers, particularly in rural areas. Government agencies, NGOs, and agricultural organizations can collaborate to offer workshops or mobile training units that teach farmers how to use smartphones, social media platforms, and digital tools effectively.
- **Solution Impact**: Empowering farmers with digital skills will increase their confidence in using social media, enabling them to access valuable agricultural content, market products, and connect with peers and experts.

**2. Improving Internet Connectivity:**

- **Recommendation**: Invest in rural broadband infrastructure and mobile network expansion to improve internet connectivity in remote areas. Governments and telecom companies can work together to provide affordable internet access or subsidized data packages tailored for farmers.
- **Solution Impact**: Enhanced connectivity will allow farmers to stay updated on agricultural trends, access online support, and engage with global markets, thus reducing the digital divide.

**3. Ensuring Reliable and Credible Information:**

- **Recommendation**: Develop platforms or apps where farmers can access verified, peer-reviewed, and region-specific agricultural information. Agricultural experts, universities, and government bodies should be involved in curating content and ensuring its accuracy.
- **Solution Impact**: By providing credible sources, farmers can make informed decisions, avoid misinformation, and adopt better farming practices, leading to improved productivity and sustainability.

**4. Enhancing Privacy and Security Measures:**

- **Recommendation**: Encourage farmers to use secure platforms and educate them about online privacy practices, such as data encryption and securing personal accounts. Governments and NGOs can also provide resources on data protection and online safety.
- **Solution Impact**: Reducing concerns about privacy and security will increase farmers' willingness to engage with social media, sharing information and collaborating with others more freely.

**5. Curating Relevant Content:**

- **Recommendation**: Create social media channels and online communities specifically for farmers in different regions, languages, and crop types. Content should be localized to meet

farmers' specific needs and challenges, whether it's related to weather, pests, or market prices.
- **Solution Impact**: Tailored content will make it easier for farmers to find practical advice and solutions that are directly applicable to their farming practices, leading to better engagement and application of knowledge.

**6. Affordable Technology and Devices:**

- **Recommendation**: Provide low-cost smartphones, tablets, and internet packages for farmers through government schemes or partnerships with tech companies. Additionally, farmers could benefit from discounts on devices through agricultural cooperatives or cooperatives.
- **Solution Impact**: Access to affordable technology will ensure more farmers can participate in the digital agriculture ecosystem, boosting their capacity to use social media effectively.

**7. Promote Cultural Adaptation and Acceptance:**

- **Recommendation**: Engage local agricultural leaders, influencers, and respected community figures to advocate for the benefits of social media in farming. Demonstrating success stories of farmers who have benefited from social media can help change mindsets.
- **Solution Impact**: When local leaders advocate for digital adoption, farmers may be more inclined to embrace new technologies, overcoming cultural barriers and building trust in the digital tools.

**8. Develop Platforms with Local Language Support:**

- **Recommendation**: Develop or promote agricultural platforms that support multiple local languages and dialects. This can help overcome language barriers and ensure that farmers can engage with content in a language they are comfortable with.
- **Solution Impact**: By offering content in native languages, more farmers will be able to access and benefit from social media resources without facing language barriers.

**9. Strengthen Government and Private Sector Collaboration:**

- **Recommendation**: Governments, NGOs, and private sector companies should collaborate to create initiatives that provide farmers with practical digital tools, educational resources, and reliable agricultural platforms. Joint efforts can ensure that digital tools are designed to address specific farming needs.
- **Solution Impact**: A collective approach from multiple sectors will ensure that the challenges are addressed holistically, fostering a sustainable digital agriculture ecosystem.

**Success Story: "Digital India" and the Role of WhatsApp in Agricultural Advancements**

In India, **WhatsApp** has become an incredibly valuable tool for farmers, particularly in the state of **Madhya Pradesh**. The state government, in partnership with agricultural organizations, launched a program called **"Digital Green"** to improve agricultural practices through mobile-based technology. Farmers were introduced to WhatsApp groups where they could receive information on crop diseases, weather updates, and best farming practices in real time.

**Key Elements of Success:**

- **WhatsApp for Knowledge Sharing**: Farmers in these WhatsApp groups exchange agricultural tips, solutions for pest control, and advice on crop management. The groups also provide timely weather alerts and government scheme updates.

- **Improved Access to Experts**: Farmers who had no access to agricultural extension services were able to directly communicate with experts and share photographs of their crops for advice.
- **Increased Yield and Profitability**: As a result of this digital intervention, farmers reported higher yields, reduced crop losses, and better decision-making, leading to an increase in income.

**Failure Story: The Challenges of Misinformation in Social Media**

While social media can be a powerful tool, it also has its pitfalls. A **failure story** from the state of **Uttar Pradesh**, India, highlights the issue of **misinformation** that can spread on social platforms, leading to significant consequences for farmers.

In 2020, during the early stages of the **COVID-19 pandemic**, rumors about a supposed **fertilizer shortage** and exaggerated **market prices** spread rapidly through WhatsApp groups and Facebook. Many farmers, acting on this misinformation, over-purchased fertilizers and seeds, only to find that the rumors were false.

**Key Challenges Faced:**

- **Misinformation**: Farmers were misled by false information on social media regarding product shortages and price hikes, which led to unnecessary financial losses.
- **Lack of Verification**: The absence of proper checks and credible sources in some agricultural groups led to the spread of rumors and inaccurate agricultural advice.
- **Negative Impact on Livelihoods**: The incorrect purchases and decisions based on misinformation left farmers in financial distress, as they had invested more money than needed into supplies that were ultimately not required.

**Lessons Learned:**

- **Success**: The **Digital Green** initiative in Madhya Pradesh showcases how the correct use of social media platforms can directly improve agricultural practices, enhance access to information, and boost farmers' productivity.
- **Failure**: The Uttar Pradesh case highlights the need for credible sources of information on social media. Misinformation can lead to harmful financial consequences, especially when farmers rely on unverified advice.

## Conclusion

Social media has great potential to transform agriculture, these challenges can hinder its effective adoption and use by farmers, particularly in rural and underserved areas. Addressing issues like digital literacy, connectivity, and information reliability will be key to maximizing the benefits of social media for agriculture. By addressing these challenges with targeted interventions, farmers can be empowered to use social media effectively, leading to better productivity, improved market access, and enhanced agricultural development. Overall, when used effectively and responsibly, social media has the potential to significantly improve the lives of farmers, help them stay informed, and connect them to global markets, thus contributing to the advancement of agriculture.

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## CLIMATE CHANGE AND AGRICULTURE

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**Abstract**
Over the last 50 years, human activities, particularly the burning of fossil fuels have released sufficient quantities of carbon dioxide and other greenhouse gases to trap additional heat in the lower atmosphere and affect the global climate. Extreme weather events are becoming more intense and frequent. The turn of the twenty-first century has borne witness to the seemingly relentless march of climate change. The likely changes that climate change will bring in temperature, precipitation and extreme rainfall, drought, flooding, storms, sea-level rise and environmental health risks and anticipated impacts on agriculture from climate change have been critically evaluated and the needed adaptation measures including changes needed for mitigation to improve agriculture sector.

**Introduction**
One of the major challenges facing humankind is to provide an equitable standard of living for present and future generations: adequate food, water, energy, safe shelter and a healthy environment. But, global environmental issues such as land degradation, loss of biodiversity, stratospheric ozone depletion along with human-induced climate change, threatens our ability to meet the basic human needs. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reaffirms that the climate is changing in ways that cannot be accounted for by natural variability and that 'global warming' is happening. Global mean temperatures have risen (0.6$^{o}$C in the last century), with the last decade being the warmest on record. Climate change will, in many parts of the world, adversely affect socio-economic sectors, including water resources, agriculture, forestry, fisheries and human settlements, ecological systems and human health, especially in developing countries due to their vulnerability.

India is already experiencing a warming climate. Unusual and unprecedented spells of hot weather are expected to occur far more frequently and cover much larger areas. Under 4°C warming, the west coast and southern India are projected to shift to new high-temperature climatic regimes with significant impacts on agriculture. Climate change impacts on agriculture and livelihoods can increase the number of climate refugees leading to conflict.

Recent estimates report that global food production must increase by 70% to meet the projected food demand of the estimated 9 billion global population by 2050. With a population of about 1.3 billion, it is evident that the food system in India will be central to the global challenge of providing sufficient nutritious food while minimising GHG emissions. Agriculture is sensitive to short-term changes in weather and to seasonal, annual and long term variations in climate. Climate change will have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand and trade. The magnitude and geographical distribution of such climate-induced changes may affect our ability to expand the food production as required to feed the increasing population. Climate change could thus have far reaching effects on the patterns of trade among nations, development and food security. To keep global warming possibly below 1.5 °C and mitigate adverse effects of climate change, agriculture, like all other sectors, will have to contribute to efforts in achieving net negative emissions by the end of the century.

**Greenhouse Gases**

Greenhouse gases are those that absorb and emit infrared radiation in the wavelength range emitted by Earth. The most abundant greenhouse gases in Earth's atmosphere are - Carbon dioxide ($CO_2$), Methane ($CH_4$), Nitrous oxide ($N_2O$), Ozone ($O_3$), Chlorofluorocarbons (CFCs) and Hydrofluorocarbons (incl. HCFCs and HFCs).

**Carbon dioxide ($CO_2$)**: Fossil fuel use is the primary source of $CO_2$. It can also be emitted from direct human-induced impacts on forestry and other land use, such as through deforestation, land clearing for agriculture, and degradation of soils. Likewise, land can also remove $CO_2$ from the atmosphere through reforestation, improvement of soils, and other activities. 100-year global warming potential of $CO_2$ is 1.

**Methane ($CH_4$)**: Production and transport of coal, natural gas, and oil are the main source. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills. 100-year global warming potential of methane is 21. Average lifetime in the atmosphere is 12 yrs.

**Nitrous oxide ($N_2O$)**: Agricultural activities, such as fertilizer use, and industrial activities, as well as during combustion of fossil fuels and solid waste are the primary source. 100-year global warming potential of $N_2O$ is 310. Average life time in the atmosphere is 114 yrs.

**Fluorinated gases (F-gases)**: Industrial processes, refrigeration, and the use of a variety of consumer products contribute to emissions of F-gases, which include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$). 100-year global warming potential of Fluorinated gases varies. Average lifetime in the atmosphere varies from few weeks to thousands of years.

Black carbon is a solid particle or aerosol, not a gas, but it also contributes to warming of the atmosphere.

**Ozone:** The ozone layer present in the stratosphere acts as a protective shield. It saves the earth from the harmful ultraviolet rays of the sun. The compounds containing CFCs (chlorofluorocarbons) are mainly responsible for ozone layer depletion as these compounds react with ozone in the presence of ultraviolet rays to form oxygen molecule and thus, destroying ozone. Scientists have already found an ozone hole over the South Pole. Once the ozone layer is depleted, ultraviolet rays will pass through the troposphere and eventually to earth. These rays cause aging of the skin, skin cancer, cataract and sunburn to humans as well as animals. Phytoplankton dies in the presence of ultraviolet rays which results in a decrease in fish productivity. Chlorofluorocarbons and other halocarbons are held responsible for ozone layer depletion.

**Greenhouse Gases Emissions**

According to the latest report by PBL Netherlands Environmental Assessment Agency, trends in global $CO_2$ and total greenhouse gas (GHG) emissions show that India's emissions have gone up by 4.7% in 2016. For most major GHG emitters in the world, the emission figures have gone down, barring India and Indonesia. In 2016, the five largest emitting countries and the European Union accounted for 68% of total global $CO_2$ emissions and about 63% of total global GHG emissions. About 72% of the emissions consist of $CO_2$, however, methane ($CH_4$), nitrous oxide ($N_2O$) and fluorinated gases (F-gases) also make up substantial shares of 19%, 6% and 3%, respectively. Over the past two years, total global greenhouse gas emissions, excluding those from land use change and forestry, have shown a slowdown in growth, reaching 49.3 gigatonnes $CO_2$ equivalent in 2016. At the global scale, the key greenhouse gases emitted by human activities are given in Fig 1 and Global greenhouse emissions by the sectors in Fig.2 (IPCC, 2014) and by the countries in Fig. 3.

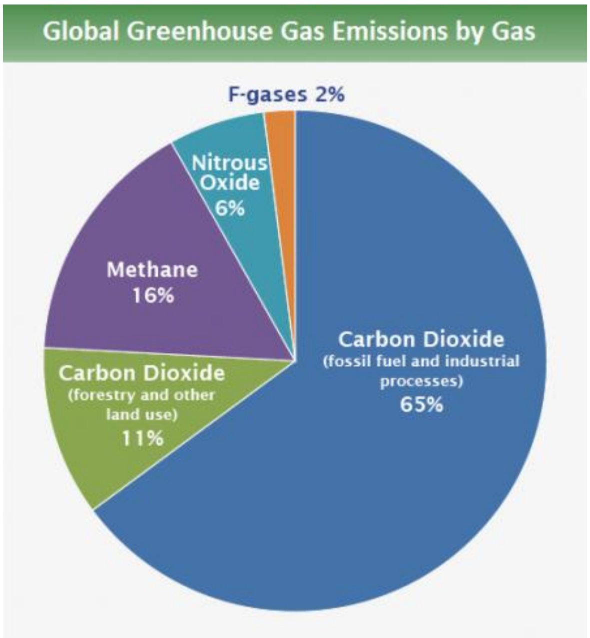


Fig. 1 Global greenhouse emissions by gas. Source: IPCC (2014) Based on global emissions from 2010. Details about the sources included in these estimates can be found in the "Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change".

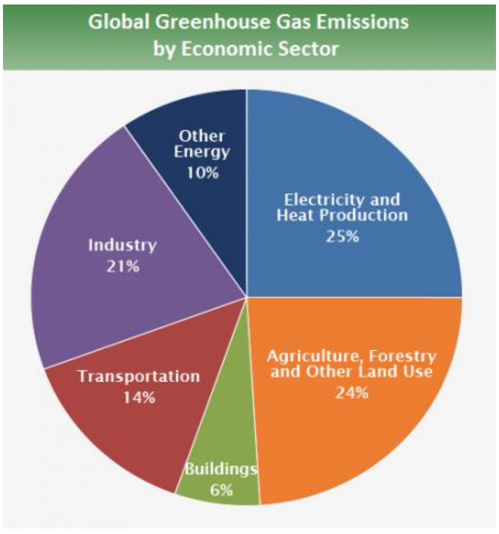


Fig. 2 Global greenhouse emissions from economic sectors. Source: IPCC (2014); based on global emissions from 2010. Details about the sources included in these estimates can be found in the *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

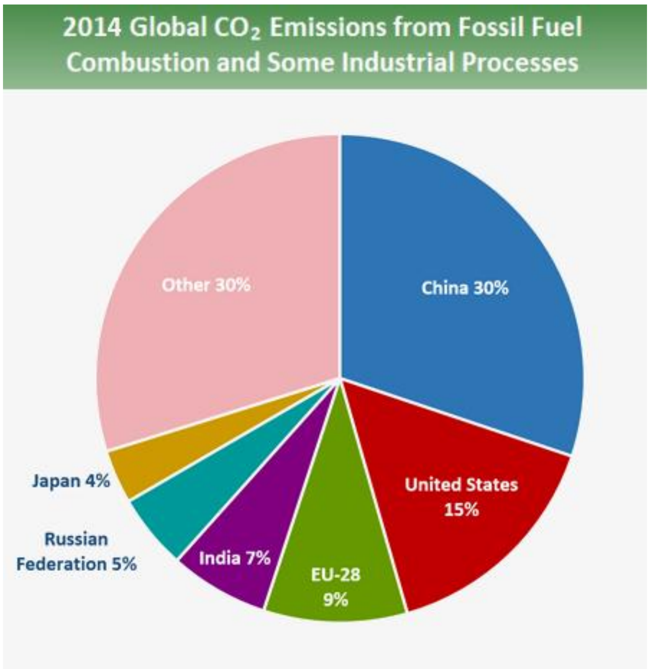


Fig. 3.Global $CO_2$ emissions from fossil fuel combustion and some industrial processes

Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, doi 10.3334/CDIAC/00001_V2017.In 2014, the top carbon dioxide ($CO_2$) emitters were China, the United States, the European Union, India, the Russian Federation, and Japan. These data include $CO_2$ emissions from fossil fuel combustion, as well as cement manufacturing and gas flaring. Together, these sources represent a large proportion of total global $CO_2$ emissions.

**Greenhouse Effect**

The greenhouse effect is a natural phenomenon that can be described as the capacity of the atmosphere of absorbing and retaining sun rays' humidity and warmth. This is why the presence of these gases is crucial for life on Earth. Without greenhouse gases, and thus Earth's atmosphere, the average temperature would be -18$^0$C, while the greenhouse effect keeps the average temperature around 14-15$^0$C.

**Consequences of Greenhouse Effect**

Climate change will alter the world in which we live. It has manifold effects on nature, society and economy, and thereby also on our everyday lives. These effects are referred to as climate impacts and are summarized below:

***Extreme Heat :*** The average temperatures that humans are exposed to are significantly higher than the global surface average because most people live on land, where warming happens most quickly. The number of "vulnerable" people exposed to "heatwave" events increased by around 125 million between 2000 and 2016. In 2015, a record 175 million more people were exposed to heatwaves, when compared to the average for 1986-2008. **Fig. 3** shows the change in the number of people exposed to heatwaves from 2000 to 2016, relative to 1986-2008 (**Fig. 4**)

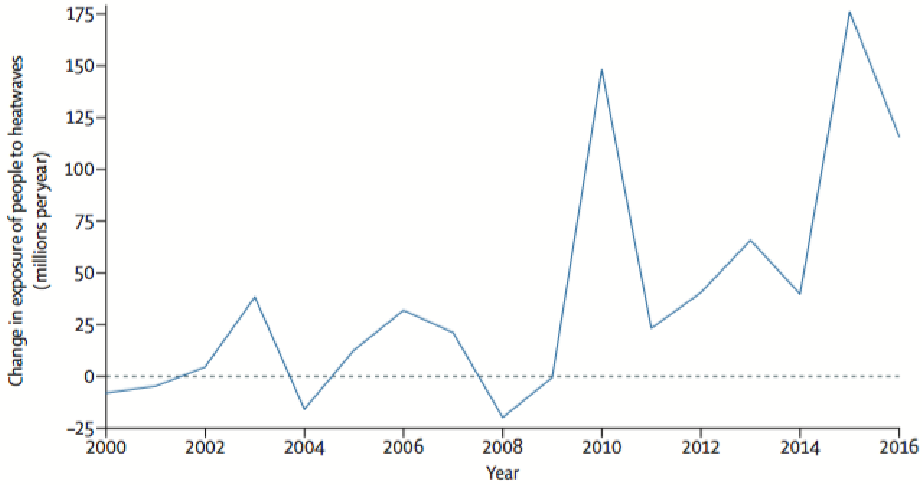


Fig.4. Change in the number of people exposed to heatwaves per year from 2010 to 2016 (blue), relative to the 1986-2008 average

Apparently, of all climate-related projections rising temperatures are the most robust. Because winter temperatures are rising faster than summer ones, old-related deaths are likely to decline. Increase in carbon dioxide concentrations and temperatures will be affecting the timing of aeroallergen distribution and amplifying the allergenicity of pollen and mold spores. One way that higher temperatures threaten labour capacity is by making manual work more physically challenging. Higher temperatures pose profound threats to occupational health and labour productivity, particularly for people undertaking manual, outdoor labour in hot areas. Loss of labour capacity has important implications for the livelihoods of individuals, families, and communities, especially those relying on subsistence farming.

Warmer oceans and other surface waters may also mean severe cholera outbreaks and harmful bacteria in certain types of seafood. A warmer world would bring changes in "disease vectors"- the mechanisms that spread some diseases. Insects previously stopped by cold winters are already moving to higher latitudes (toward the poles). Warmer temperatures and higher concentrations of carbon dioxide in the atmosphere stimulate some plants to grow faster, mature earlier, or produce more potent allergens. Common allergens such as ragweed seem to respond particularly well to higher concentrations of $CO_2$, as do pesky plants such as poison ivy. Allergy-related diseases rank among the most common and chronic illnesses that can lead to lower productivity.

**Ozone depletion :** Higher temperatures and increased sunlight would increase ground level ozone and fine particle concentrations, which can trigger a variety of reactions including chest pains, coughing, throat irritation, and congestion, as well as reduce lung function and cause inflammation of the lungs.

**Poor air quality :** Three key ingredients-sunlight, warm air, and pollution from power plants and cars burning coal and gasoline, combine to produce ground-level ozone (smog), which humans experience as poor air quality. Higher air temperatures increase smog, if sunlight, fossil fuel pollution, and air currents remain the same.

**Melting Glaciers :** At 2.5°C warming, melting glaciers and the loss of snow cover over the Himalayas are expected to threaten the stability and reliability of northern India's primarily glacier-fed rivers, particularly the Indus and the Brahmaputra. The Ganges will be less dependent on melt water due to high annual rainfall downstream during the monsoon season. The Indus and Brahmaputra are expected to see increased flows in spring when the snows melt, with flows reducing subsequently in late spring and summer. Alterations in the flows of the Indus, Ganges, and Brahmaputra rivers could significantly impact irrigation, affecting the amount of food that can be produced in their basins as well as the livelihoods of millions of people (209 million in the Indus basin, 478 million in the Ganges basin, and 62 million in the Brahmaputra basin in the year 2005).

**Increasing sea levels :** Rising sea levels and increasingly extreme weather events will destroy homes, medical facilities and other essential services. More than half of the world's population lives within 60 km of the sea. People may be forced to move, which in turn heightens the risk of a range of health effects, from mental disorders to communicable diseases. Kolkata and Mumbai, both densely populated cities, are particularly vulnerable to the impacts of sea-level rise, tropical cyclones, and riverine flooding.

**Warmer ocean waters:** Warmer ocean waters may spawn more intense tropical hurricanes and typhoons while ocean cycles continue to be a factor in the frequency of tropical cyclone. The number of weather-related disasters from 2007 to 2016 increased by 46%, when compared with the average for 1990-1999. Asia is the continent most affected by weather-related disasters, particularly because of its size and population. Between 1990 and 2016, 2,843 weather-related disasters were recorded in Asia, affecting 4.8 billion people and causing more than 500,000 deaths.

**Water Security:** Many parts of India are already experiencing water stress. Even without climate change, satisfying future demand for water will be a major challenge. Urbanization, population growth, economic development, and increasing demand for water from agriculture and industry are likely to aggravate the situation further. An increase in variability of monsoon rainfall is expected to increase water shortages in some areas. The threat to water security is very high over central India, along the mountain ranges of the Western Ghats, and in India's north-eastern states. The Indus and the Ganges-Brahmaputra-Meghna Basins are major trans boundary rivers, and increasing demand for water is already leading to tensions among countries over water sharing. India is a hotspot for the migration of people from disaster-affected or degraded areas to other national and international regions. India's water ministry found in a study last year that 16% of India's ground water resources are over exploited. In Delhi, Punjab, Haryana and Rajasthan groundwater extraction is beginning to exceed annual water availability. States like Gujarat, Karnataka and Tamil Nadu are exploiting close to 70% of their ground water reserves. Added to this is the fear that weakening monsoons are failing to replenish the falling water tables.

**Drought:** Changing precipitation patterns and prolonged heat can create drought, which can cause forest and peat fires, putting residents and firefighters in danger. In extreme cases, water scarcity leads to drought and famine. By the late 21st century, climate change is likely to increase the frequency and intensity of drought at regional and global scale. Droughts are expected to be more frequent in some areas, especially in north-western India, Jharkhand, Orissa and Chhattisgarh. Crop yields are expected to fall significantly because of extreme heat by the 2040s. More than 60% of India's agriculture is rain-fed, making the country highly dependent on groundwater. Projected changes in temperature and precipitation under global warming are likely to lead to other effects that threaten human health and safety.

**Changing Rainfall Patterns:** A 2°C rise in the world's average temperatures will make India's summer monsoon highly unpredictable. At 4°C warming, an extremely wet monsoon that currently has a chance of occurring only once in 100 years is projected to occur every 10 years by the end of the century. An abrupt change in the monsoon could precipitate a major crisis, triggering more frequent droughts as well as greater flooding in large parts of India. India's northwest coast to the south eastern coastal region could see higher than average rainfall. Increasingly variable rainfall patterns are likely to affect the supply of fresh water. A lack of safe water can compromise hygiene and increase the risk of diarrhoeal disease, which kills over 500,000 children aged under 5 years, every year. Increased precipitation in some areas would also lead to an increase in mold spores.

**Increasing Incidence of Floods:** Floods are also increasing in frequency and intensity, and the frequency and intensity of extreme precipitation is expected to continue to increase throughout the current century. Floods contaminate freshwater supplies, heighten the risk of water-borne diseases, and create breeding grounds for disease-carrying insects such as mosquitoes. They also cause drownings and physical injuries, damage homes and disrupt the supply of medical and health services. Floods are also increasing in frequency and intensity, and the frequency and intensity of extreme precipitation is expected to continue to increase throughout the current century. Floods contaminate freshwater supplies, heighten the risk of water-borne diseases, and create breeding grounds for disease-carrying insects such as mosquitoes. They also cause drownings and physical injuries, damage homes and disrupt the supply of medical and health services. Rising temperatures and variable precipitation are likely to decrease the production of staple foods in many of the poorest regions. This will increase the prevalence of malnutrition and undernutrition, which currently cause 3.1 million deaths every year.

A schematic diagram of Greenhouse effect is presented in Fig.4 which makes it clear how the solar radiation is responsible for greenhouse effect.

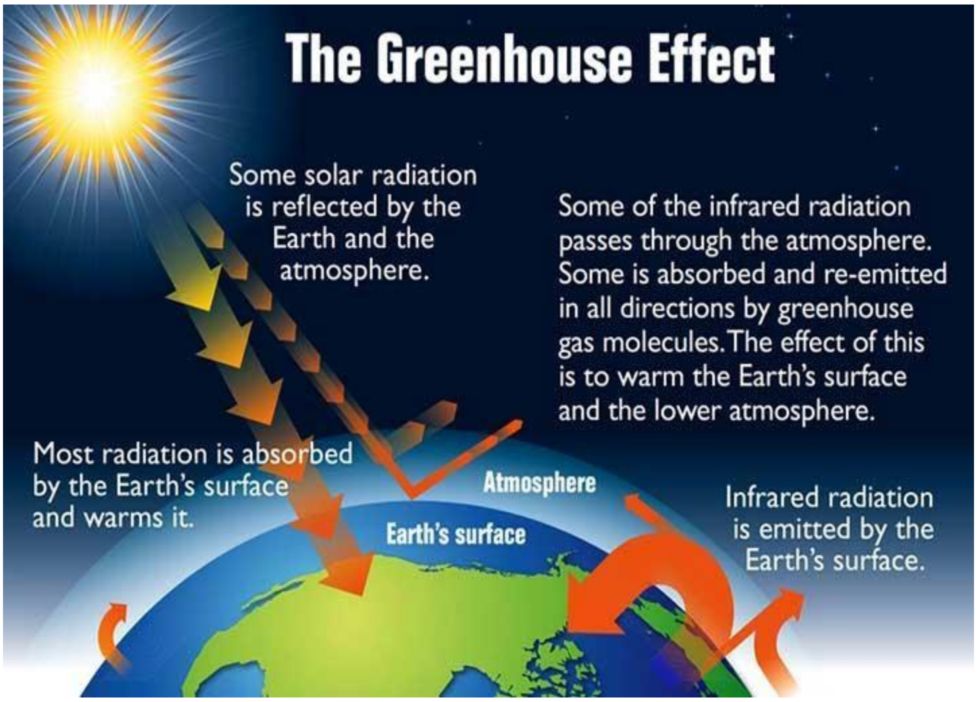


Fig. 4. A schematic diagram of Green house effect

**GHG Emissions Related to Agriculture**

Agricultural production is a major emitter of GHGs in India and contributes to climate change both by anthropogenic emissions of greenhouse gases and by the conversion of non-agricultural land such as forests into agricultural land. Agriculture, forestry and land-use change contributed around 20 to 25% to global annual emissions in 2010 (Blanco, 2014). The global agriculture contributed about 11% to the total global GHGs emission, the share of Indian agriculture was about 7%. Agricultural production accounts for 18% of total GHG emissions in India. Despite the total 21% contribution to the total GHGs emission from India it was only 1% of the total global emission from all the sources. The per-capita GHGs emissions from agriculture have decreased from both India and the world in 2010 vis-a-vis 1970.

The highest GHG emissions among crops are associated with paddy rice production. Emissions of $CH_4$ from rice production are recognised as a significant source of GHG emissions globally, and many studies show that changes in water management can substantially reduce $CH_4$ emissions. Quantification of GHG emissions from the production of different food commodities helps farmers, researchers and policymakers to understand and manage these emissions, and identify mitigation responses that are consistent with the food security and economic development priorities of the country.

**GHG Emissions from Food Consumption in India**

Proportion of consumption of food groups in Indian diets and distribution of GHG emissions from agricultural production of this diet are shown in Fig. 5 A and 5B respectively which show their relative contribution to emissions. Rice and livestock products contribute the most to total dietary GHG emissions, with the third contributor being ruminant meat. Although ruminant meat had the greatest GHG emissions *per* unit product, it contributed less to overall GHG emissions (12.5%) as consumption is low, accounting for only 0.4% of total intake. Cereals other than rice and fruit products account for 12.9% and 22.5% of reported consumption by weight, yet as their emissions *per* unit of product are low, they make a relatively small contribution to total dietary GHG emissions, representing only 3.2% and 1.1% of total emissions, respectively. The group "other" (including various crops from the subgroups nuts and oils, spices, and vegetables) also contributed little to total dietary GHG emissions.

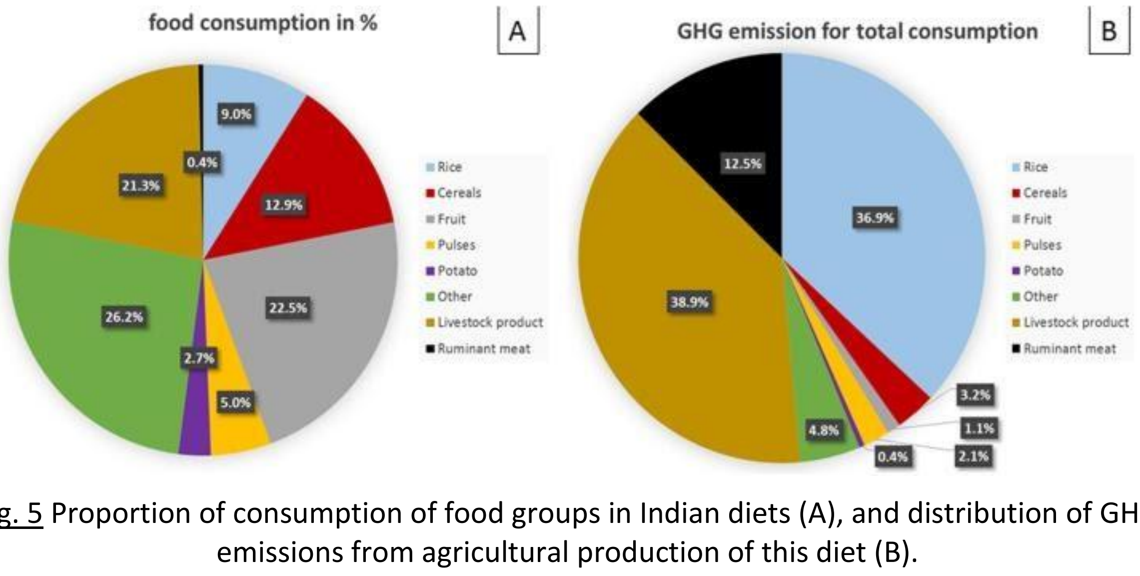


Fig. 5 Proportion of consumption of food groups in Indian diets (A), and distribution of GHG emissions from agricultural production of this diet (B).
Source: Silvia et al. (2017)

GHG emissions from livestock products are generally higher than those from crop production. This reflects the inefficiencies of conversion of plant protein to animal protein in herbivores. Ruminants produce $CH_4$ through enteric fermentation, and options to mitigate this source are somewhat limited. Other sources of emissions from livestock production are manure management and changed feed rations. To reduce GHG emissions from manure management options include (i) changes to manure storage, e.g. decreased storage time, manure storage cover with straw, or mechanical intermittent aeration during manure storage, (ii) manure acidification, (iii) feeding of livestock with nitrate supplements and (iv) stacking of poultry litter. To reduce GHG emissions from feed, all mitigation measures as for the crops are to be considered. The crop residues from crop production may be utilised as fodder or recycled in the soil.

GHG emissions *per* kg of livestock product varies markedly between livestock types being the highest for mutton meat (as the example for ruminant meat), followed by other livestock production such as poultry and dairy (milk). Mean GHG emissions were <1 kg $CO_2$eq $kg^{-1}$ product for all crops except rice, with decreasing emissions across the categories of spices, pulses and nuts, wheat, fruits, vegetables and roots, and sugarcane, respectively. GHG emissions *per* kcal show a different ranking, although products from ruminant animals have the highest emissions using all metrics.

**Effect of Climate Change on Agriculture**

Climate change can affect agriculture in a variety of ways. Beyond a certain range of temperatures, warming tends to reduce yields because crops speed through their development, producing less grain in the process. And higher temperatures also interfere with the ability of plants to get and use moisture. Evaporation from the soil accelerates when temperatures rise and plants increase transpiration—that is, lose more moisture from their leaves. The combined effect is called "evapotranspiration." Because global warming is likely to increase rainfall, the net impact of higher temperatures on water availability is a race between higher evapotranspiration and higher precipitation. Typically, that race is won by higher evapotranspiration. But a key culprit in climate change-carbon emissions-can also help agriculture by enhancing photosynthesis in many important, so-called C3, crops (such as wheat, rice, and soybeans). The science, however, is far from certain on the benefits of carbon fertilization. But we do know that this phenomenon does not much help C4 crops (such as sugarcane and maize), which account for about one-fourth of all crops by value.

The yields for cereals, pulses and potatoes have increased over recent years in India, but are still only half of those recorded in Western Europe and North America (FAOSTAT, 2015). These differences show the importance of comparing GHG emissions on a *per*-kg-production-basis, as GHG emissions will be greater for low yielding crops than for higher yielding ones using a *per*-kg metric. For instance, according to FAOSTAT (2015) rice yields in China are around twice those in India. It is possible to reduce $CH_4$ emissions and increase yield through optimising drainage and manure management. Specifically, changing a continuously-flooded system to intermittent irrigation shows potential to greatly reduce $CH_4$ emissions. Potential and constraints of greenhouse gas mitigation options. are presented in Table1.

**Table 1. Potential and constraints of greenhouse gas mitigation options**

| Option | Mitigation (%) | Constraints |
|---|---|---|
| 1. Methane from rice field | | |
| • Intermittent drying | 25-30 | Assured irrigation |
| • Direct-seeded rice | 30-40 | Machine, herbicide |
| • SRI | 20-25 | Labour, assured irrigation |
| 2. Methane from ruminants | | |
| • Balanced feeding | 5-10 | Cost, open grazing |
| • Feed additives | 5-10 | Cost, biosafety |
| • Efficient animals | 10-20 | Cost, acclimatization |
| 3. Nitrous oxide from soil | | |
| • Site-specific N use | 10-15 | Awareness, fertilizer policy |
| • Nitrification inhibitor | 10-15 | Cost, incentive |
| 4. Carbon sequestration in soil | | |
| • Conservation agriculture | 15-20 | Continuity, smallholding |
| • Organic farming | 15-25 | Manure availability, cost |

*Source: Pathak et al. (2010)*

**Epilogue**

India's agriculture system is facing serious challenge and risks due to climate change. According to a recent study by Nature and Climate Change, global agriculture productivity has reduced by 21% since 1961. Food systems represent a third of total greenhouse gas emissions and are a major contributor to biodiversity loss. Although, technologies to boost climate resilience and reduce the carbon footprint of agriculture are often known and tested, however, there is no clear road map for the types of mitigation and adaptation measures, smallholder farmers can adopt and how do they prioritize investments and efforts to support those measures. The bigger challenge in the countries like India is to create awareness among farmers, train and finance them to adopt mitigation and adaptation strategies to achieve the goal of climate resilient agriculture that is economically viable, socially responsible, and environmentally sound.

Despite the resounding success in grain growth, it has been observed that yields of many crops have begun to stagnate as a consequence of imbalanced fertilization and decline in organic matter content of soils. In India. nitrogenous fertilizers, particularly urea is heavily subsidized by the government and thus its application is more obvious than other nutrients. Excessive N fertilizer-use affects groundwater and also causes eutrophication in aquatic ecosystems. The imbalanced fertilization is considered a serious concern rapidly deteriorating the soil health.

If Indian agriculture is to attain its broad national goal of sustainable agriculture growth of over 4%, it is important that the nanotechnology research is extended to the agricultural total production -

consumption system, that is, across the entire agricultural value chain. This would require focusing on technologies that increase agricultural productivities, product quality and resource-use efficiencies that reduce on-farm costs, raise the value of production, and increase farm income; as well as on conserving and enhancing the quality of the natural resource base. It would also require a conscientious effort to provide a system to deliver these innovations based on nanotechnology to a product delivery stage and ensure that these reach the rural stakeholders at the end of the agri-value chain.

The developing countries are most at risk, so it is strongly in their own interest that they participate actively in international abatement programs. China already produces larger carbon dioxide emissions than the European Union and will soon surpass those of the United States. Global emissions from developing countries (including from deforestation) are already equal to those from industrial countries, and are growing faster. It is striking that the two largest developing countries, India and China, seem to have potentially conflicting interests in their approach to international abatement efforts. With broadly neutral or even positive effects on its agriculture, China could be less interested in international efforts to restrain emissions than India, which faces major potential losses if there is no change in global emissions policies. But even in China, some key subregions are at risk.

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# COMMERCIAL AGRICULTURE: THE BACKBONE OF GLOBAL FOOD PRODUCTION

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## Abstract
Commercial agriculture plays a crucial role in global food production, focusing on large-scale farming aimed at selling crops and livestock in the market rather than growing for personal consumption. This approach marks a shift from traditional farming, where the primary goal is to produce food for the farmer's family. In commercial agriculture, the emphasis is on maximizing profits through higher yields, efficient use of resources, and the adoption of advanced technologies. Key features include large-scale operations, specialized crop selection, reliance on machinery, integration with global supply chains, and the involvement of agribusiness corporations. Different types of commercial agriculture, such as dairy farming, grain farming, and livestock ranching, are practised around the world, often influenced by local climates and resources. Despite its success, the sector faces challenges like climate change, market fluctuations, and economic uncertainties. To ensure its future, sustainable farming practices, such as agroecology and regenerative agriculture, are gaining attention, supported by government policies and collaborative efforts. With the right strategies in place, commercial agriculture can continue to feed the world while becoming more resilient and sustainable.

**Keywords:** Innovation, trade, sustainability, Production, truck farming

## Introduction
Commercial agriculture refers to farming practices centered on producing agricultural goods primarily for market sale rather than for personal subsistence. This approach departs from traditional farming, where small-scale farmers mainly cultivated crops or reared livestock to fulfill household needs. The primary goal of commercial agriculture is profit generation, achieved through maximizing yields and optimizing resource utilization (Abeysiriwardana and Jayasinghe-Mudalige, 2022). Advanced technology and mechanization are integral to this system, enhancing productivity and efficiency. Furthermore, commercial agriculture involves

Image source: https://media.geeksforgeeks.org/wp-content/uploads/20230711173545/Commerical-Farming-.webp specialization, strategic crop selection based on market trends, integration with global supply chains, and active involvement of agribusiness corporations (Kulikov *et al.,* 2020). These defining characteristics have contributed to its prominence in contemporary agricultural practices.

**Key Characteristics of Commercial Agriculture**

Several distinct features differentiate commercial agriculture from other farming systems and highlight its operational dynamics.

1. **Large-Scale Production and Economies of Scale**: Commercial agriculture often operates on extensive tracts of land or involves large-scale livestock production. These operations leverage economies of scale, enabling cost reductions through bulk purchasing, streamlined mechanization, and efficient resource allocation.
2. **Advanced Technology and Mechanization**: The use of modern machinery, precision farming techniques, and advanced equipment is central to commercial agriculture. These innovations increase productivity, lower labour requirements, and optimize the use of inputs such as water, fertilizers, and pesticides.
3. **Specialization and Market-Oriented Crop Selection**: Commercial farmers prioritize the cultivation of high-value crops aligned with market demands. This strategic specialization ensures efficient resource allocation and minimizes the risks associated with surplus production.
4. **Global Supply Chain Integration**: Commercial agriculture is characterized by its connection to international trade networks and export-focused production. These linkages contribute to economic growth, foreign exchange generation, and enhanced access to global markets.
5. **Role of Agribusiness Corporations**: Agribusiness companies significantly influence commercial agriculture by providing essential inputs, services, and financing. Their involvement shapes production practices and impacts the structural dynamics of the agricultural industry (Temoso *et al.,* 2024).

**Types of Commercial Agriculture**

Commercial agriculture encompasses diverse practices, each tailored to specific aspects of food production and livestock management. This diversity reflects its adaptability to different ecological, economic, and cultural contexts. It also encompasses a variety of farming practices designed to produce food, raw materials, and other products for industrial and consumer markets. The following are the main types of commercial agriculture:

Image source: Tractor

1. **Dairy Farming: -** Dairy farming involves the breeding of milk-producing animals, such as cows, buffaloes, camels, and sheep, to produce milk and dairy products. These products are either processed in dairy plants or sold directly to consumers. Farming can occur on dedicated farms or in commercial dairy facilities.
2. **Grain Farming: -** Practised primarily in tropical regions, such as India, grain farming focuses on large-scale production of crops like rice, wheat, maize, and millet. Mechanized farming equipment, such as threshers and harvesters, is essential for this type of agriculture. Different grains are

cultivated in regions where climate conditions, such as temperature and water availability, are favourable for their growth.

3. **Plantation Farming: -** Historically significant during the colonial era, plantation farming involves the large-scale cultivation of cash crops, including coffee, rubber, cocoa, tobacco, and fruits. These farms typically require vast tracts of land and rely on manual labour, especially during harvest periods. In India, plantation farming is prominent in the production of tea, with key areas including Kerala and West Bengal.
4. **Fruit Farming: -**Fruit farming involves the cultivation of both exotic and common fruits such as dragon fruit, bananas, apples, and oranges. The demand for these products is global, and farming practices often utilize high-yield varieties and pesticides to maintain large-scale production.
5. **Livestock Ranching:-** Livestock ranching focuses on the rearing of animals for meat production. Common livestock includes cattle, sheep, pigs, and chickens, with products such as beef, pork, and chicken supplied to markets and consumers, particularly in urban areas and restaurants.
6. **Mixed Farming: -**Mixed farming combines both crop cultivation and livestock rearing on the same farm. This practice may include activities such as beekeeping alongside fruit or horticulture farming, where livestock waste is utilized as fertilizer for crops, thereby promoting a sustainable farming system.
7. **Horticulture: -** Horticulture involves the commercial production of ornamental plants and flowers, which are in high demand for decorative and ceremonial purposes. These farms face significant challenges, particularly due to pests, which make the use of pesticides crucial in maintaining crop health and productivity.

The types and practices within commercial agriculture vary across regions, influenced by factors such as climate, resource availability, and cultural preferences. This diversity underscores the sector's flexibility in adapting to market dynamics and optimizing production methodologies to address consumer needs (Komarek *et al.,* 2020).

**Challenges in Commercial Agriculture**

- **Climate Change**
    - Unpredictable weather patterns and increased frequency of extreme events
    - Shifting growing seasons disrupt crop production and livestock management
    - Need for adaptation through crop diversification, improved water management, and precision farming techniques
- **Economic Uncertainty and Market Fluctuations**
    - Volatility in commodity prices, trade policies, and market demand
    - Impact on profitability and financial stability of farmers
    - Limited access to capital, technology, and markets, especially for small-scale farmers

**Strategies for Sustainability in Commercial Agriculture**

- **Sustainable Farming Practices**
    - Adoption of organic farming, conservation agriculture, and agroforestry
    - Focus on soil conservation, water efficiency, and biodiversity preservation
    - Reduction in chemical inputs to enhance environmental health
- **Agroecology and Regenerative Agriculture**
    - Holistic approaches to improve soil health, biodiversity, and ecosystem services

  - Practices like cover cropping, crop rotation, and integrated pest management
  - Soil fertility improvement, carbon sequestration, and natural pest control

**Role of Government Support and Policy Interventions**

- **Policy Initiatives**
  - Financial incentives, technical assistance, and research and development for sustainable agriculture
  - Encouraging the adoption of sustainable farming practices through government programs
- **Collaboration for Sustainability**
  - Coordination between governments, farmers, researchers, and agribusinesses
  - Collaborative efforts to address challenges and promote long-term sustainability in commercial agriculture.

**Conclusion**

In conclusion, commercial agriculture plays a crucial role in feeding the world and supporting economic growth. Its ability to produce large quantities of food and raw materials, along with the integration of technology and global supply chains, has made it an essential part of modern agriculture. However, it also faces significant challenges such as climate change, market instability, and environmental concerns. To ensure that commercial agriculture remains sustainable in the long run, it's important to adopt eco-friendly farming practices like agroecology and regenerative agriculture. With the right support from government policies and collaboration between farmers, researchers, and businesses, commercial agriculture can adapt to future challenges while continuing to meet global food demands responsibly and sustainably.

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# DISEASE MANAGEMENT IN BANANA- A WAY FOR HEALTHY FRUIT PRODUCTION

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After mangos, bananas (*Musa* sp.) are India's second-most important fruit crop. It is the most popular fruit among all social classes due to its year-round availability, cost-effectiveness, variety, flavor, and nutritional and therapeutic benefits. It has good export potential as well. With a yield of 97.5 million tons, bananas are a significant fruit crop on a global scale. Millions of people in India rely on it for their livelihood. 28.45 million tons are produced annually from 959 thousand hectares, with a national average of 35.7 tons per hectare (Meenakshi and Monikanda Prasad, 2022). In India, the banana accounts for 37% of all fruit production. In India, bananas make nearly 20% of the entire cultivated area. In India, Maharashtra has the highest production and the second-largest area. High-tech growing the crop is a profitable business that increases output, improves the quality of the produce, and matures the crop early, resulting in premium-priced fruit.

A number of significant banana diseases have surfaced and spread geographically during the past century. Plant diseases such as yellow and black Sigatoka, fusairum wilt, freckle leaf spot, banana bunchy top and banana bract mosaic virus and Moko and Xanthomonas wilt are threatening banana production worldwide.

**Fusarium wilt /Panama disease**

Fusarium wilt often known as Panama disease, was initially discovered in Australia in 1874 (Bancroft, 1876). Nowadays, practically every tropical and subtropical banana-producing region has fusarium wilt infection. It is brought on by *Fusarium oxysporum* sp. *cubense* (FOC), a soil fungus of the relatively common genus. The global banana production was threatened by a destructive soil-borne fungus, namely Fusarium oxysporum f. sp. cubense (Foc) (Bubici *et al*., 2019).

Externally, the earliest symptoms appear as yellowing of the lowermost leaves, which progresses upward from the border to the midrib. Eventually, the heart leaf alone stays green for a while and is also impacted. The leaves hang down around the pseudostem after breaking close to the base. In extreme situations, the pseudostem will divide longitudinally. Vascular vessels will get discolored and show red or brown streaks if the sucker is cut open in a crossing fashion.

**Mode of spread and survival**

In essence, the pathogen is soil-borne. It has a longer lifespan in soil as chlamydospores. Infected rhizomes are the disease's major means of transmission, while irrigation water is its secondary means. Continuous cultivation of banana encourages accumulation of inoculum in the same field.

**Management**

The management of the disease is still a challenge to banana growers.

- Susceptible cultivars viz., Rasthali, Monthan, Red banana and Virupakshi may be avoided. Instead, Poovan may be cultivated.

- Health suckers should be selected for planting purpose.
- Paring and pralinge practice to be followed if suckers infection. The side roots and outer skin of suckers are to be removed and dipped fungicidal solution containing 0.2 per cent Carbendazim. Then the suckers may be dipped in clay slurry and sprinkled with Carbofuran granules at 40g/corm.
- Adequate care should be taken irrigation should not run through infected plants because irrigation water may carry inoculum to other health plant in nearby area.
- Application of Carbendazim at 2% level as corm injection @ 3 ml in the corm by making a hole to a depth of 10cm with $45^0$ angle on 5 th and 7 th month after planting.
- Soil drenching of Carbendazim 0.2 per cent solution alternated with Propiconozole 0.1% around the pseudostem at bimonthly intervals starting from five months after planting
- Crop rotation with paddy may be followed for one or two seasons to reduce inculum level of pathogen in soil.

**Sigatoka leaf spot diseases**

The sigatoka leaf spot disease is also serious one and there are two main types viz., Black Sigatoka and Yellow Sigatoka may appear on the banana plants. Black Sigatoka (also called black leaf streak disease or BLS) is caused by the fungal leaf parasite *Mycosphaerella fijiensis*.

**Symptoms**

The symptoms first manifested as tiny, narrow, light yellow or brownish green stripes that ran parallel to the veins on leaves. They grow into oblong, linear, brown to black spots with a yellow halo and a dark brown mark. Large, asymmetrical patches of desiccated tissue are created when the spots combine. In the impacted leaves, black dots of fungal fruitification show up. In extreme situations, the leaves will quickly dry down and become defoliated.

**Management**

- Spray carbendazim @ 1 g/l or mancozeb @ 2 g/l or copper oxychloride @ 2.5 g/l or ziram @ 2 ml/l or chlorothalonil @ 2 g/l at monthly interval from November onwards.
- Spray pyraclostrobin 133 g/l + epoxiconazole e 50g/l SE @ 3 g/l or tebuconazole 50% + trifloxystrobin 25% WG @ 300 g/ha

**Freckle or Black Spot**

**Symptoms**

The fungus *Phyllostictina musarum* is responsible for the disease. The fungus produce minute raised dark brown spots with black dots in the centre on leaves as well as on fruits. The infection is limited to the fruit's skin.

**Management**

Spraying of Carbendazim 0.1 % or Propicanozole 0.1 % or Mancozeb 0.25% or Calixin 0.1% with teepol (sticking agent) at 10-15 days interval, as the disease starting from initial appearance of leaf specks in lower side of the leaf.

**Moko disease**

*Ralstonia solanacearum* is the cause of the disease, and the affected plant will exhibit leaf yellowing that advances upward. The affected leaves will hand down. A cross section of the pseudostem (or corm) shows that the core part of the corm is discolored and ranges in color from pale yellow to dark brown. An additional indication of bacterial infection is the presence of copious amounts of bacterial exudate. The bacterium colonizes every vascular bundle in the fruits through the rachis if the affected plant produces a fruit bunch. fruits with interior rot and a dark brown discoloration.

**Management**

- The infected plants should be eradicated from field
- The field should be maintained as weed free and stubble, debris free condition.
- The disease free planting material to be used.
- Implements used for intercultural operations should be cleaned and disinfected if necessary

**Banana *Xanthomonas* Wilt (BXW)**

Banana Bacterial Wilt Disease (BBW), caused by *Xanthomonas campestris* pv. *musacearum* The symptoms are observed above all on the emergence of spear leaves, especially at flowering. Flower bracts become discoloured and the male bud blackens and shrivels. The leaves yellow, wilt, blacken, dry and crumble (including the pseudostem). Yellow or brown vascular streaks are observed throughout the plant together with pale bacterial secretion on a section at the base of the pseudostem or at the corm. This cause bunches to wilt, with premature maturation and a reddish brown colour inside the fruit. The plant dies within a month of the appearance of any of these symptoms (one month after infection). The disease is spread by foraging insects, infected plant material (suckers, bunches and leaves), tools and man, and also by animals, run-off, rainwater splashes and wind. There are no resistant varieties.

**Virus diseases**

In recent years, virus diseases of banana are spread rapidly due to diversification of the crop. They include mosaic disorders such as bract mosaic, banana streak disease, and banana bunchy top disease. Losses due to the diseases are varied, however; it affects all types of banana. Sometimes, the bunchy top virus cause 100 per cent yield loss. Where as banana bract mosaic virus claimed yield loss of more than 40%.

**Banana bunchy top disease (BBTV)**

Infected plants are stunted and rosetted at the top. Leaves are reduced in size marginal chlorosis and curling. Leaves upright and become brittle. Many leaves are crowded at the top. Branches size will very small. If infected earlier no bunch will be produced. The narrow, erect, brittle leaves display strongly chlorotic borders. The characteristic symptom is the appearance of discontinuous dark green streaks along the pseudostem, the main leaf vein and the secondary veins. When the mother plant is infected, so are all the suckers. The disease is transmitted primarily by infected suckers and after infection, the disease transmitted by banana aphid *Pentalonia nigronervosa*.

**Management**

- Suckers for planting should be selected from disease free areas.
- Apply carbofuran 3G @ 166 g /plant or spray dimethoate 30EC @ 1 ml/l or methyl demeton 25 EC @ 2 ml/l to control vector
- The spray may be directed towards crown and pseudostem base upto ground level at 21 days interval at least thrice.
- In order to prevent further spread of virus, fully infected plants should be destroyed properly by inserting a gelatin capsule containing 200 mg 2,4 - D into the corm 7 cm deep using

capsule applicator or inject 5 ml 2,4 - D solution (125 gm/lit of water) into the pseudostem by using the injection gun. The plant will be collapsed and toppled in 3 – 5 days.

**Banana mosaic**

The disease caused by cucumber mosaic cucumovirus (CMV). Infected plants exhibits leaf chlorosis and mottling of the main vein and the pseudostem. The virus can be spread by a broad range of aphids.

**Banana streak disease (BSV)**

Narrow, intermittent, and occasionally continuous chlorotic or yellow lines that extend from the leaf midrib to the margin are the most typical symptoms. Sometimes there are patterns in the shape of spindles or eyes. Banana streak has also been linked to yellow blotches. Both concentrated and scattered symptoms are possible. The lamina may occasionally become deformed. Later, streaks turn orange and frequently turn brown or black. The petiole and midrib have also been shown to exhibit necrosis.

**Banana bract mosaic (BBrMV)**

The symptoms are characterized by the presence of spindle shaped pinkish to reddish streaks on pseudostem, midrib and peduncle. Typical mosaic and spindle shaped mild mosaic streaks will be appeared on bracts, peduncle and fingers. Infected plants suckers will exhibit unusual reddish brown streaks at emergence and separation of leaf sheath from central axis. The virus is transmitted through aphid vectors. The virus is primarily spread through infected suckers. In the field, aphids vectors such as *Aphis goosypii* and *Rhopalosiphum maidis* transmits the disease.

**Management**

- The infected plants should be removed as and when noticed to avoid the spread of the disease
- Disease free planting materials should be used for new planting
- Weeds in the nearby areas should be removed as the virus survives in them in off-season
- The vector transmission can be prevented by spraying phosphomidon at 1 ml per litre or methyl demeton at 2 ml per litre

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# SELF-MEDICATION IN INSECTS

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**Abstract**

Studies have shown that the medication behaviors exhibited by insects are far more prevalent than previously recognized. Bees, ants, flies, and butterflies can utilize a variety of toxic and nutritional compounds to medicate themselves or their genetic kin. This medication can occur in response to active infections (therapy) or in anticipation of high infection risks (prophylaxis), and it serves to enhance resistance or tolerance to infections. Although significant advancements have been made in recent years, there are still crucial areas that need thorough investigation. These areas include assessing the costs of medication, particularly at the colony level in social insects, and developing theoretical models that can predict how infection risk influences micro-evolutionary and macro-evolutionary trends in animal medication behaviors.

**Key words :** Kin, pharmacophagy, pharmacophory, prophylactic medication, therapeutic medication, Zoopharmacognosy, etc.

## Introduction

Medication refers to the targeted use of anti-pathogenic substances by infected individuals, resulting in measurable benefits to host fitness while negatively impacting the pathogen (Abbott, 2014). Organic compounds derived from plants, utilized in both traditional human medicine and animal self-medication, are widely regarded as valuable resources for the discovery of novel drugs (Huffman, 2003). Self-medication is typically defined as the deliberate use of organic compounds to help eliminate a parasitic infection or alleviate its symptoms (Lozano, 1998). We interpret self-medication as a form of adaptive plasticity, defined by environmentally induced changes in behavior or phenotype during an individual's lifetime that enhance survival and reproductive success. Adaptive plasticity is particularly likely to evolve when there is a consistent trade-off in the adaptive value of different phenotypes under varying ecological conditions. It has long been known that certain insects use ingested plant compounds for defense (Ode, 2006). Most research on self-medication in insects has focused on its effects on resistance, though there is at least one documented case of enhanced tolerance.

## Zoopharmacognosy:

Humans are not the only inhabitants of the earth. We have shared our planet with several other organisms, they too get diseases and they have their ways to cure it. Vertebrate herbivores may gain medicinal benefits from the secondary metabolites present in their plant-based diets. The term *Zoopharmacognosy*, coined in 1993, originates from the Greek words *zoo* (animal), *pharma* (drug), and *gnosy* (knowing). Zoopharmacognosy refers to a behavior observed in non-human animals, in which they appear to self-medicate by selecting and ingesting or topically applying plants, soils, insects, or psychoactive substances to treat and prevent harm caused by pathogens, toxins, or other animals (Mamillapalli *et al.,* 2016).

**Medication in Vertebrates**:
A lot of animals out there in the world they took their medicines themselves (Roode *et al.*, 2013). Examples *viz*., Chimpanzee drinks Juice of the plant *Vernonia amygdalina* (Delile) to get rid of intestinal parasites. Baboons Eat bark of albizzia tree to overcome gastrointestinal disorders. Dogs consume grass to overcome upset stomachs and parasites in gut. Birds like red and green macaws eat clay rich in sodium which can help in digestion and can kill bacteria. Sparrows and finches collect used cigarette butts left by the humans and keep it inside their nests to protect themselves and their offspring from ticks and mites.

**Medication in Insects:**
Insects face threat from other organisms that prey on them and other microbes that infects and cause diseases. In order to deal with this, insects have evolved a wide range of defense mechanisms. An insect's first lines of defense against infection are structural for example cuticle and peritrophic matrix, midgut membrane that act as barriers to the pathogen entry. Once the cuticle is breached, the innate immune system is activated, involving processes such as melanization, encapsulation and the production of antimicrobial peptides acts on the pathogen to protect it from getting diseased. If these two defenses fail then medication will only be the alternative. Medication in insects is broadly divided into two types (Roode and Hunter, 2019).

**1. Kin medication:** Kin medication is medicating their genetic kin including offspring and other genetic relatives rather than themselves. Medication in case of genetic relatives is mainly seen in case of eusocial Hymenoptera. These ants and bees collect the resin from different plants which are antiparasitic in nature and store them mainly to protect their colony from the pathogen infection. Kin medication can be transgenerational medication or medication of genetic relatives. Examples for transgenerational medication includes medication in monarch butterfly where the infected monarch females lay eggs on the milkweed plants which are rich in cardenolides to protect their offspring from infection. And drosophila melanogaster selectively lays eggs in food rich in ethanol if the fly notices an activity of parasitic wasp which can attack fly larva. And the parasitic wasps are not observed to lay eggs on fly feeding on ethanol-rich food (de Roode *et al*., 2013).

**Trans generational medication in monarch butterfly:**
*Ophryocystis elektroscirrha* is a protozoan parasite that is widespread across the range of monarch butterflies, significantly reducing their fitness by impairing adult lifespan, mating success, fecundity, and flight ability. Infection begins when monarch larvae ingest infective spores deposited on eggshells or milkweed leaves by infected females during oviposition. Once ingested, the spores lyse in the larval gut, releasing sporozoites that penetrate the midgut wall and invade the host's hypoderm. The parasite then undergoes vegetative asexual replication, followed by sexual reproduction during the monarch's pupation. Upon eclosion, adult butterflies emerge from their chrysalis coated in infective spores, which do not replicate further. For new infections to occur, these spores must be ingested by larvae. Several scientists have attempted to study the behavioural mechanisms by which monarch butterfly larvae medicate to escape from infection. And they have found that monarch butterfly larvae cannot differentiate eggs or plants with or without infectious parasite spores; infected larvae don't show any preference for therapeutic food plants. "Whereas

the infected adult female monarch butterflies exhibited a strong oviposition preference on plants containing secondary anti metabolites which will prevent their offspring from getting diseased. (Lefevre *et al*.,2010).

**2. Self-medication:** Self-medication is medicating themselves with the use of organic compounds specifically for the purpose of helping to clear a (parasitic) infection or diminish its symptoms.

**Criteria for self-medication (Singer *et al*., 2009)**

1. The substance in question must be in deliberate contact
2. The substance must harm one or more parasites
3. The increased host fitness must result from the substance's detrimental effect on parasites
4. The substance must have a detrimental effect on host in absence of parasites

**Self-medication in woolly bear caterpillar *Grammia incorrupta***

Woolly bear caterpillar *Grammia incorrupta* are broad generalist grazers. In *nature g. incorrupta* caterpillars are attacked by three parasitoids like *Carcelia reclinata* and *Exorista mella* both belonging to tachinidae family and braconid parasitoid *Cotesia phobetri*. These parasitoids lay their eggs in caterpillar hosts, where their larvae feed and develop before emerging to pupate, ultimately killing the hosts. The woolly bear caterpillar ingests Pyrrolizidine alkaloids from specific host plant species, sequestering these compounds in haemocoel and integument of the caterpillar (Singer *et al*., 2009).

**Self-medication in Fruit flies:**

Fruit fly drosophila melanogaster is mainly attacked by larval Endoparasitoids like *Leptopilina boulardi* and *Leptopilina heterotoma*. In the fruit fly, both therapeutic and prophylactic transgenerational medication are seen. In therapeutic self-medication, Infected larvae of fruit fly prefer to feed on food with more ethanol content. Here ethanol consumption increases plasmatocyte number in fly larvae thereby increasing encapsulation response. And in case of prophylactic transgenerational medication the female lay eggs in the food containing a higher amount of alcohol when they notice the activity of female wasps**.** (Milan *et al.*,2012).

**Social Medication:**

The deliberate use or consumption of plant compounds by social insects, which harm a parasite or pathogen at the colony level, leads to increased inclusive fitness benefits. Social-medication is distinct from self-medication in that the host is the colony, not the individual. (Spivak *et al.*, 2019). Plant secondary metabolites are not only found in leaves but are also common in floral rewards such as pollen and nectar. floral nectar contains secondary metabolites like phenols, terpenes and alkaloids (including nicotine, anabasine, gelsemine) (Baracchi *et al*., 2015).

**Role of alkaloids in reduction of the infection (Manson *et al*., 2010)**

- Secondary metabolites fight against pathogens.
- It causes physical or chemical changes to the gut lining or induce diuresis
- It increases gut pH
- Increase excretion which helps in flushing out the *Crithidia* cells from the body
- It upregulates bee immune response
- Stimulate endosymbiont gut bacteria of bees

**Pharmacophagy and Pharmacophory:**
Bees utilize native or processed hive products in two distinct pharmacological ways: pharmacophagy and pharmacophory. Pharmacophagy involves defense mechanisms derived from the direct consumption of substances such as honey, pollen and royal jelly to reduce disease or enhance honeybee health. In contrast, pharmacophory relates to the use of non-edible hive products, such as propolis and resin, for protective purposes (Erler and Moritz, 2016).

**Self-medication in Bumble bees:**
Bumble bees are important pollinators in nature and they are frequently parasitized by a wide range of different microorganisms. *Crithidia bombi* (Trypanosomatidae) is a common gut parasite of bumble bees, *Bombus terrestris*. The parasite primarily infects adult bees, with infective cells being released through faeces of bees in two to three days after infection. Queens infected by *C. bombi* have shown reduced success in colony founding and produce fewer reproductive offspring. Infected workers face higher mortality under stressful conditions, which impairs their learning and foraging abilities.

To investigate whether bumblebees can self-medicate by consuming naturally occurring nectar with secondary metabolites. Baracchi *et al*., (2015), conducted a series of experiments using a *B. terrestris* and *C. bombi* as models and nicotine as a natural nectar alkaloid. The results showed that continuous exposure to a nicotine-enriched diet reduced the intensity of *C. bombi* infections in worker bees of *Bombus terrestris* (Linnaeus). However, delayed exposure to nicotine, provided two hours before inoculation, had no impact on parasite load. Furthermore, preference tests revealed that infected bumblebees were significantly more likely to visit nicotine-rewarding flowers compared to their healthy counterparts.

**Self-medication in honey bees:**
Honeybees employ several prophylactic disease defense strategies, including foraging of antibiotic, antifungal, and antiviral compounds of plant products. As a result, honey and pollen contain various compounds that inhibit fungal and bacterial growth and suppress viral replication. Since these compounds are also passed to the larvae by nurse bees, they play a crucial role in maintaining colony health within the hive Gherman *et al.,* (2014).

**Self-medication in Ants:**
Beauveria bassiana is a common entomopathogenic fungus that infects ants, killing individuals from various species within four days of infection. The corpses of infected ants can further spread the fungus to others. In response to the high pathogen pressure, ants have evolved a variety of physiological and behavioural strategies, one of which is self-medication.

Rissanen *et al.,* (2022) conducted an experiment to test how different levels of infection by *Beauveria bassiana* affect the self-medication behaviour of *Formica fusca* ants in the form of foraging choices of colonies and whether they lead to enhanced survival against the pathogen. The results showed that access to different diets significantly influenced the foraging activity of the ant *Formica fusca* (Linnaeus) within colonies. Foraging activity was notably lower on a fixed ROS diet (4% $H_2O_2$) compared to both the control diet and the food choice diet. However, no significant difference in foraging activity was observed between colonies with access to the control diet and those with the food choice diet.

**Conclusion**

The phenomenon self-medication in insects is a fascinating testament to the adaptive capabilities within the insect world. Wooly bear caterpillar, Monarch butterfly, Fruit fly, these creatures display intricate behaviors in response to parasitic threats, showcasing active substance contact, detrimental effects on parasites, and subsequent improvements in host fitness. The introduction of 'social-medication' underscores the collective immune strategies employed by eusocial insects like Honey bees, Bumble bees and Ants, further enriching our understanding of insect colonies' defense mechanisms. The delicate balance between nutritional gains and the medicinal consumption of phytochemicals highlights the complexity of these adaptive behaviors.

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# SUSTAINABILITY PRACTICES IN AGRICULTURE IN ANCIENT INDIA

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**Abstract**

Vedic agriculture, a method characterized by sustainability, emerges from the fertile soil of ancient India. It embodies environmentally friendly techniques; these practices can indeed be applicable to modern civilization, however, it is important to recognize that they hinge upon the utilization of natural products derived from flora and fauna, serving both as pesticides and fertilizers to enhance plant growth promoters. The maintenance of growth in plants is contingent upon various external factors—such as sunlight and water—yet it is also profoundly influenced by the soil in which they thrive. Soil, rich in diverse microorganisms, facilitates the flourishing of plants; among these, one finds plant growth promoting rhizobacteria i.e., PGPR. In antiquity, cow dung alongside other natural materials notably served to bolster crop yields. Moreover, it incorporates a myriad of natural products: milk, honey, ghee and water—all integral to seed germination techniques. Cow dung and cow urine harbor bacteria that significantly improve plant growth. This experiment elucidates the distinctions in plant growth resulting from the application of cow dung and cow urine, juxtaposed with typical plants, thereby elucidating the practical implications of Vedic agricultural methodologies in fostering sustainable agriculture.

**Key words:** agriculture, environment, plant growth, cow dung, cow urine, fertilizers.

## Introduction

Agriculture in ancient India also referred to as Vedic agriculture or krishi represents a venerable Indian methodology toward horticulture, emphasizing a harmonious relationship with nature and the deployment of indigenous strategies for crop cultivation. It is grounded in the principles of Vedic logic, which can be traced back over 5,000 years. Krishi, or farming, in antiquated India constituted an imperative portion of the economy, fundamentally rooted in the Indus Valley Civilization[1].

The Vedic Period (1): Individuals during this era employed implements such as hals, hansi and chalni to cultivate grains including wheat, rice and barley. They also adopted a crop rotation system to enhance soil fertility. Old writings such as the Rigveda, alongside other texts like Naradasmriti, Vishnu Dharmottara Purana and Agni Purana, provide references to agriculture. Krishi Parashara stands out as a seminal work specifically addressing farming, containing verses like "Krishir dhanaya krishir medhya jantunam jeevanam krishi," which translates to "Agriculture is wealth, farming is insights and agriculture is the foundation of human existence."

However, this intricate tapestry of agricultural practices not only underscores the significance of sustenance but also reflects the philosophical underpinnings of ancient Indian society. Although the tools and methods might seem rudimentary by contemporary standards, they embodied a profound understanding of ecological balance and sustainability.

Indus Valley Civilization: Archeological evidence which is compelling posits that individuals within the Indus Valley Civilization were, in fact, advanced agriculturists. They cultivated wheat and grain among other crops and, moreover, because of their sophisticated methods paid taxes in the form of grains. Mauryan Period: This era witnessed the establishment of agricultural officials, whose purpose was to enhance agribusiness and rural production. Greek traveler Megasthenes noted that the sovereign appointed authorities to ensure however, this was a challenging task equitable distribution of water in canals and their tributaries. Post-Independence: Following India's acquisition of independence, the government with great urgency introduced high-yielding seeds and various agricultural innovations, leading to a significant increase in food production and the Green Revolution.

**Key highlights of Vedic agriculture:**
Natural and normal: No manufactured fertilizers, pesticides, or hereditarily altered life forms (GMOs) are employed; however, the ethos of organic cultivation remains paramount. Soil preservation—strategies such as trim turn, mulching and cover editing—works to uphold soil health, because the integrity of the earth is at stake. Broadened crops developing diverse varieties in tandem serve to imitate characteristic ecosystems; this method enhances biodiversity. Agroforestry refers to the integration of trees into cultivating frameworks, which not only advances environmental balance but also enriches the landscape. Cow-based cultivating employs dairy animals waste and urine as natural fertilizers and pest control agents, thus fostering a closed-loop system. Moon-based planting, which aligns crop cycles with lunar phases, optimizes development and yield; although some might question its efficacy, the results often speak for themselves. Otherworldly association emerges as farmers cultivate a spiritual relationship with the land, plants and animals. Krishi Parashara, an ancient Indian text, addresses agriculture, farming and animal husbandry; it is considered one of the most significant works on Vedic horticulture indeed, it is ascribed to the sage Parashara, who purportedly lived around 1500 BCE. This text serves as a comprehensive guide to sustainable and organic farming practices, covering a wide range of themes, including the intricate interplay of nature and cultivation.

1. Soil planning and richness management
2. Seed determination and treatment
3. Edit revolution and intercropping
4. Water system and water management
5. Bother and malady management

Animals' administration and creature husbandry represent a complex interplay of ethical considerations and practical necessities; however, the intricacies involved in such a domain often elude the untrained eye. This multifaceted field necessitates a profound understanding of not only the biological imperatives of various species (1) but also the socio-economic factors that underpin their management. Although the endeavor may seem straightforward, it is fraught with challenges e.g., resource allocation, environmental impact. Because of these variables, practitioners must navigate a labyrinth of regulations and ethical dilemmas. However, the pursuit of sustainable practices remains paramount in fostering a harmonious relationship between humans and the animal kingdom.

7. Rural cosmology and lunar cycles
8. Cultivating methods and tools

Krishi Parashara a work of remarkable significance is widely regarded as a seminal text on Vedic horticulture, having received extensive veneration throughout the centuries. Its principles and practices remain notably relevant, offering invaluable insights into sustainable and eco-friendly agricultural methodologies. Comprising 12 chapters, each dedicated to a distinct facet of farming and cultivation, this text is articulated in Sanskrit and has been translated into various languages, including English, Hindi and numerous regional dialects. Among the Vedic agricultural practices delineated in Krishi Parashara are: 1. The assessment of rainfall correlated with the celestial positions of the Moon and Sun; 2. Identification of productive versus unproductive soils; 3. A detailed characterization of 12 land types based on soil fertility, irrigation capabilities and physical attributes; 4. Crop irrigation utilizing river water through channels as well as well water; 5. The critical importance of high-quality seeds and their treatment; 6. The application of natural pest and disease management techniques; and 7. The utilization of organic manure and composting. However, the richness of these practices transcends mere agricultural utility, for they encapsulate a holistic perspective on the interplay between nature and cultivation. Although modern agricultural science has evolved, the teachings of Krishi Parashara continue to resonate, illustrating the timeless nature of such wisdom. This text remains not only a historical document but also a guide for contemporary practices, reminding us that sustainable agriculture is both an art and a science, interwoven with the cultural fabric of society.

**Trim turn and intercropping**

The planting of crops which corresponds to seasonal variations and lunar cycles is a practice steeped in tradition; however, it also demands a nuanced understanding of agricultural dynamics. Utilizing characteristic cures (1) for pest and infection management is essential, because these methods not only enhance yield but also promote sustainability. Although some may argue that modern techniques supersede these practices, this assertion overlooks the profound wisdom embedded in the rhythms of nature. Therefore, integration of these time-honored approaches is necessary, even as we navigate the complexities of contemporary agriculture.

**Integration of animals in agrarian systems**

Vedic farming points to:

1. Advance soil fertility
2. Moderate water
3. Bolster biodiversity
4. Upgrade environment services
5. Progress edit resilience
6. Back country livelihoods
7. Cultivate a association with nature

By embracing Vedic rural homes, ranchers and those dedicated cultivators can contribute to a more maintainable and ecologically cognizant nourishment system. Vedic farming, which utilizes conventional and common strategies methods, to develop crops, embodies an ancient wisdom. A few of the strategies practices utilized in Vedic horticulture include.

1) Beeja Siddhi: seed treatment utilizing normal substances like bovine fertilizer, pee and ghee to improve seed vitality
2) Jeevamrutha: a characteristic fertilizer made from dairy animals waste, pee, jaggery and flour, advancing soil microbiology.

3) Panchagavya: a concoction of bovine drain, curd, ghee, pee and compost, utilized as a fertilizer and bother controller.
4) Vaastu Shanti: adjusting ranches with the earth's vitality network—this method ensures ideal trim (crop) development and health.
5) Homa Cultivating: utilizing fire ceremonies to filter the climate, enhance soil quality and advance trim growth—however, one must be cautious of the practices' intricacies
6) Edit Revolution: turning crops to keep up soil richness (this is crucial), diminish bugs and maladies and advance biodiversity
7) Natural Fertilizers: utilizing characteristic materials like compost, vermicompost and green fertilizer to enhance soil health—although many still overlook these potent strategies.
8) Agroforestry: The integration of trees within cultivation frameworks aims to enhance environmental equilibria (adjust) and promote soil conservation.
9) Polyculture: The practice of cultivating diverse crops simultaneously seeks to replicate natural ecosystems, thereby mitigating pestilence and disease.
10) Common Pest Control: The utilization of neem, turmeric, alongside other natural substances, serves to manage pests and ailments. These methodologies aspire to harmonize agriculture with (nature) — advancing soil health, biodiversity and ecological stability. The process of Vedic agriculture encompasses a series of stages that align with the organic cycles and rhythms of the environment. Here is an outline of this intricate process: 1. _Soil Planning_: Employing natural techniques such as crop rotation, organic fertilizers and panchagavya to enhance soil fertility and structure. 2. _Seed Selection_: Choosing high-quality seeds that are well-suited for local climatic conditions and soil profiles (however, this selection is critical). 3. _Seed Treatment_: Enhancing seeds using natural agents like beeja siddhi to bolster their vitality and disease resistance. Although there exist several seed germination methods employed in Vedic horticulture, the emphasis remains on employing nature's wisdom (because) it is fundamental to sustainable practices.

Seed treatment (as practiced by Vedic agriculturists) involves a meticulous covering of seeds with flour derived from rice, dark gram and sesame, thereby ensuring optimal germination. Dairy animals compost treatment is another fascinating approach; the utilization of dairy waste serves as a means to treat seeds, particularly those of cotton. Panchagavya is, however, a more intricate concoction: a blend of five components sourced from dairy, which includes matured bovine fertilizer, urine, milk, curd and ghee. Compost tea, a technique employed by Vedic ranchers, aims to enhance seed germination significantly. Seed selection, an essential step, sees Vedic agriculturists carefully choosing high-quality seeds that are particularly suited to local climate and soil conditions. Sowing occurs at an appropriate time, dictated by lunar cycles and soil readiness this is crucial. Crop care which often incorporates natural methods such as jeevamrutha, panchagavya and homa cultivating aims to promote robust growth and manage pests effectively. Pruning and training of plants, although labor-intensive, are conducted to maximize growth and yield, ensuring the plants reach their full potential. Harvesting demands precision; crops must be collected at the right moment to guarantee maximum quality and yield. Post-harvest care, essential for preserving and storing crops for subsequent use, employs natural methods that reflect a deep understanding of agricultural cycles. Finally, soil restoration which involves renewing soil richness and structure post-harvest is crucial for preparing the ground for future cultivation endeavors. Vedic farming emphasizes an all-encompassing approach to cultivation, considering the interconnections of soil, plants, creatures and people. By following these steps, agriculturists can create (a) sustainable and regenerative agricultural system. Here are several benefits of Vedic agriculture; however, one must also recognize (the) complexities involved. Although the methodology appears straightforward, it demands intense understanding of ecological dynamics. This ancient practice intertwines with modern needs and perspectives, because it fosters a holistic relationship among all elements involved.

**Increments trim quality and quantity**

**Diminishes chemical utilize in farming**

Moves forward in a manner that is both nuanced and complex taste, surface, estimate and dietary esteem of crops; however, one must consider the intricate interplay of factors influencing these elements. This becomes particularly salient (1) when examining the myriad ways in which cultivation techniques evolve—because soil composition, climate and even human intervention play pivotal roles. Although taste may seem subjective, it is deeply rooted in both cultural preferences and agricultural practices. But, as we delve deeper into these dimensions, we uncover layers of meaning that transcend mere consumption.

**Increments benefit for farmers**

**Secures the environment from pollutants**

Underpinning biodiversity (1) and maintaining biological balance is crucial; however, this delicate equilibrium often faces myriad threats. Although ecosystems thrive through intricate relationships, challenges arise because of human interventions. Nature's resilience is remarkable, but it requires vigilant stewardship to preserve these vital connections. Thus, understanding the complexities of these interactions becomes paramount (2), as they are not merely scientific endeavors, but essential for the sustainability of our planet.

- Moderates water
- Makes a difference in carbon sequestration
- Bolsters inborn seeds and trim diversity

Advances in feasible horticulture (1) and climate action present a potential arrangement for addressing climate change; however, the complexities involved are manifold. Although these advancements are promising, they often face significant hurdles because environmental variables can be unpredictable. This interplay between innovation and nature raises questions about sustainability (and effectiveness). Nevertheless, one must consider the broader implications: can we truly rely on these methods to mitigate the impending crisis?

- Underpins small-scale farmers
- Jam soil wellbeing and fertility

Adjusts with characteristic cycles and rhythms. The future of Vedic agribusiness holds much guarantee with potential to address worldwide nourishment security challenges: by receiving Vedic rural hones, we can increment edit yields, progress wholesome esteem and guarantee maintainable nourishment production. However, it is crucial to relieve climate alter—Vedic agriculture's emphasis on normal strategies soil wellbeing and biodiversity can offer assistance to sequester carbon, decrease outflows and advance biological balance. Although some may argue otherwise, backing feasible advancement is essential; by advancing neighborhood, natural and small-scale cultivating, Vedic farming can contribute to provincial improvement, destitution lessening and community empowerment. Furthermore, the need to protect biodiversity cannot be overstated: Vedic agriculture's center on conventional crops, seeds and cultivating hones can offer assistance protect India's wealthy agrarian legacy and biodiversity. This, in turn, may move forward rancher employments; by embracing Vedic rural hones, ranchers can increment their pay, decrease costs and enjoy way better wellbeing and well-being.

6. **Upgrade environment administrations:**
Vedic agribusiness (a term that encapsulates ancient Indian agricultural practices) can offer assistance to maintain environmental equilibrium, secure water resources and support pollinators and other beneficial organisms.

7. **Cultivate worldwide collaboration:** Vedic agriculture's principles and practices can be adapted and applied globally, promoting international collaboration and knowledge-sharing.

8. **Back India's rural development:** Vedic horticulture can significantly contribute to India's ambition of becoming a global agrarian leader—advancing economically viable and environmentally sustainable farming practices. By embracing Vedic horticulture, we can forge a more sustainable, resilient and food-secure future for generations to come. Vedic agriculture, also recognized as ancient Indian agriculture, employs holistic (albeit often misunderstood) and sustainable methods. This is a comprehensive overview of its methodology:

**Principles:**
Nature-based (1): Harmonize farming with nature's rhythms; however, the challenge lies in understanding these intricate patterns.
Holistic (2): Consider soil, plants, animals and humans interconnected, because each element influences the others profoundly.
Organic(3): Avoid synthetic chemicals and fertilizers this is crucial, although some might argue their necessity.
Self-sufficient(4): Promote local resources and minimal external inputs, but this can be difficult in a global economy.
Spiritual(5): Recognize farming as sacred, honoring the divine in nature; thus, one cultivates not just crops, but also a deeper connection to the earth.

**Preparation of Farmland:**
Panchagavya a cow-derived biofertilizer significantly enhances soil fertility; however, its efficacy though widely acknowledged can vary depending on numerous factors. Beeja Sanskar, which involves seed treatment with herbal extracts, promotes germination this is crucial for optimal crop yield because it creates a more favorable environment for growth. Agnihotra, a fire-based purification ritual, not only rejuvenates soil but also revitalizes the atmosphere although its benefits can be seen as more esoteric.

**Crop Management:**
Crop rotation is a practice of notable significance: crops must be rotated seasonally, for it is essential to maintain soil balance. Companion planting is another strategy: when crops are paired, growth is enhanced and pest control becomes more effective although the method may seem simplistic.

**Natural pest control**
employs various herbs (such as neem and turmeric), which are invaluable (because they provide a sustainable alternative to synthetic chemicals). However, one must consider that these methods require diligence and understanding; this is crucial for optimal results.

**Water Management:**
Rainwater harvesting is a vital practice: Collect and conserve rainwater, however, its implementation varies across different regions. Mulching, on the other hand, retains moisture and suppresses weeds, although its effectiveness can diminish under certain conditions. This technique is essential because it not only promotes soil health but also enhances agricultural productivity.

**3. Drip irrigation: Efficient water use.**

**Livestock Integration:**
Bovine-centric agriculture an increasingly popular practice: harnessing excrement and liquid waste from cattle as nutrient-rich fertilizers. Holistic agricultural system where various elements coexist harmoniously merging flora, fauna and arboreal growth. However, this approach is not without its challenges, because the balance between these components is delicate. Although integration offers sustainability, it requires meticulous planning.

**Tools and Equipment:**
Conventional implements: Utilize wooden plows (which are often more sustainable sickles and various eco-conscious tools. Ox-drawn vehicles: Engage in animal-propelled transportation; however, this method, while archaic, persists due to its efficiency. Although modern alternatives exist, many still prefer these time-honored approaches because they resonate with a simpler, more harmonious existence.

**Rituals and Ceremonies:**
Seed sowing ceremonies (1): They invoke divine blessings however, these rituals are not merely symbolic. Harvest festivals (2) serve to celebrate nature's abundance, but they also reflect a community's gratitude. Although these events may seem straightforward, they encapsulate a deeper connection to the cycles of life (because this bond sustains human existence).

**Key Practices:**
Zero Budget Natural Farming ZBNF: Eliminate external inputs (which can be detrimental.
Sustainable Agriculture: Balance ecology and economy (a delicate equilibrium). Agroforestry: Integrate trees into farming systems, thus enhancing biodiversity. By embracing these principles and practices, Vedic agriculture promotes eco-friendly, self-sufficient and spiritually fulfilling farming (a holistic approach). In Vedic agriculture, pesticides (although necessary at times) are derived from natural sources, minimizing harm to humans, animals and the environment. Here are some traditional pesticides (however, they remain underutilized):

**Plant-based Pesticides:**
Neem Azadirachta indica possesses an oil and leaves which are utilized to exert control over insects; however, Turmeric Curcuma longa contains an active compound—curcumin—that exhibits insecticidal properties. Although Tulsi (Ocimum sanctum) offers leaves and oil that repel pests, Garlic (Allium sativum) provides oil and extracts that effectively manage fungal diseases. Chilli (Capsicum annuum), on the other hand, yields extracts that deter pests because of their potent

nature. This intricate interplay of botanical elements reveals a complex tapestry of natural pest management strategies to be further explored.

**Animal-derived Pesticides:**
Cow urine (Gomutra)—possessing remarkable antimicrobial properties—effectively controls various fungal diseases. Cow dung (Gobar) is employed to combat pests and diseases; however, its efficacy may wane under certain conditions this is often overlooked. Although these substances serve critical roles in agricultural practices, their application must be judiciously considered, because improper use could yield adverse effects.

**Mineral-based Pesticides:**
Sulfur (Gandhak) serves as a pivotal agent in the management of fungal diseases; however, its efficacy is contingent upon various environmental factors (which may include humidity). Copper (Tamra), on the other hand, is employed to mitigate the impact of bacterial diseases although its application must be judicious. This duality of purpose underscores the complexity of agricultural practices, because both elements play crucial roles in the maintenance of crop health, yet they operate within distinct biochemical paradigms.

**Biopesticides:**
Trichoderma, a remarkable genus of fungi, engages in the control of plant pathogens; however, its efficacy is contingent upon various environmental factors. Beauveria bassiana, another fascinating fungus, effectively manages insect pests, notably some of the most destructive. Bacillus subtilis, a noteworthy bacterium, has been shown to combat plant diseases; this is significant because many crops suffer from such afflictions. Although these organisms exhibit distinct mechanisms of action, they collectively underscore the intricate relationships within ecosystems, where one organism's struggle often becomes another's salvation.

**Preparations and Methods:**
Kashaya herbal decoctions utilized as pesticides serves a crucial role in agricultural practices; however, Kwatha—herbal infusions designed to combat pests—also plays a significant part. Lepa, a paste composed of herbs and minerals, is applied to plants with the intention of enhancing their resilience. Although these methods are effective, the interplay between them is often overlooked. This complexity arises, in part, because each technique offers distinct advantages and challenges.

**Benefits:**

1. Environmentally friendly
2. Non-toxic to humans and animals
3. Cost-effective
4. Promotes biodiversity
5. Enhances soil health

**Challenges**:

1. Limited availability
2. Variable efficacy
3. Requires skilled preparation
4. Regulatory framework limitations

Through the utilization of natural pesticides, an approach rooted in ancient wisdom, Vedic agriculture significantly minimizes harm to the environment while promoting sustainable farming practices. In this paradigm, fertilizers are derived from natural sources; thus, the detrimental impact on humans, animals and the ecosystem is profoundly reduced. However, it is essential to consider that traditional fertilizers which have been employed for centuries bring their own complexities.

**Organic Fertilizers:** Gomaya (cow dung): Rich in nutrients; it improves soil structure. Gomutra (cow urine) has antimicrobial properties, enhancing soil fertility. Panchagavya—a mixture of cow dung (urine, milk, ghee and curd)—exemplifies holistic agricultural practices. Vermicompost, which involves worm composting of organic waste, contributes significantly to sustainable farming. Green manure incorporates plant residues into soil, fostering a vibrant ecosystem. However, the interdependence of these elements is profound: they sustain one another. This complexity, although beneficial, often goes unnoticed by the untrained eye.

**Plant-based Fertilizers:**

**Compost: Decomposed plant waste.**

Neem cake, a product derived from the residue of neem seeds, effectively controls pests and diseases; however, its efficacy may vary depending on environmental conditions. Tulsi manure—composed of the leaves and stems of the tulsi plant—enhances soil fertility, although the optimal application requires careful consideration. This interplay of natural elements reveals the intricate balance within ecosystems, for both neem cake and tulsi manure serve as vital contributors to sustainable agriculture (1). Because they promote healthier crops, farmers increasingly recognize their value, yet challenges remain in widespread adoption.

**Banana Leaf Compost: Rich in potassium.**

**Natural Mineral Fertilizers:**

Rock Phosphate a natural source of phosphorus serves as an essential ingredient in various agricultural practices; however, its significance extends beyond mere fertilization. This mineral, although primarily recognized for its role in enhancing soil fertility, possesses multifaceted applications in industry (1). Because of its chemical properties, it is utilized in the production of animal feed and even food processing. But, the environmental implications of its extraction and use cannot be overlooked; therefore, a balanced approach is necessary to mitigate potential drawbacks.

Lime: Calcium source, improves soil pH.

Sulfur: Natural fungicide and fertilizer.

**Biofertilizers:**

1. Rhizobium: Nitrogen-fixing bacteria.
2. Azotobacter: Nitrogen-fixing bacteria.
3. PSB (Phosphorus Solubilizing Bacteria) — enhances phosphorus availability; however, its efficacy may vary depending on environmental factors. This phenomenon can be attributed to various microbial interactions, which are complex and sometimes unpredictable. Although beneficial, the extent of enhancement is not absolute; because of this, further research is warranted.

**Preparations and Methods:**

Amrit Pani a confluence of cow urine, ghee and water represents an intriguing synthesis; however, its significance extends beyond mere ingredients. Jeevamrutha an amalgamation of cow dung, urine and water serves, therefore, as a testament to the symbiotic relationship between nature and sustenance. 3. Panchagavya Ghrita (a blend of cow ghee and cow urine) exemplifies this concept perhaps too simplistically, but it encapsulates the essence of traditional practices. Although these mixtures may appear rudimentary, their underlying philosophies reveal complexities often overlooked or misunderstood. Because of their rich historical context, they invite deeper contemplation. This multifaceted exploration of such mixtures challenges us to reconsider our perceptions of utility and tradition.

**Benefits:**
1. Environmentally friendly
2. Non-toxic to humans and animals
3. Cost-effective
4. Promotes biodiversity
5. Enhances soil health

**Challenges:**
1. Limited availability
2. Variable efficacy
3. Requires skilled preparation
4. Regulatory framework limitations

Through the application of natural fertilizers which are often derived from organic matter, Vedic agriculture not only promotes sustainable farming practices: it also enhances soil health. However, it minimizes environmental harm to a significant degree.This paradigm shift in agricultural methodology is essential, because it addresses contemporary ecological challenges. Although some may argue otherwise, the integration of these practices is beneficial for the ecosystem as a whole.

**Cow dung as plant growth promoter :**

**An experiment by Vedic Farming methods :**
In order to witness effective plant growth a phenomenon that captivates many, both milk honey and ghee were employed to enhance soil quality. A meticulous study was conducted on various plants, aiming to elucidate the effects of Ghana jeevamrutham and drava jeevamruthaam on vegetative proliferation. Experiments which are essential for gaining insight were performed on prevalent vegetable and fruit species. This methodology can indeed be extrapolated to encompass any of the plants in question. However, while utilizing this method as a biofertilizer—exemplified by cow dung and cow urine—it is imperative that no chemical fertilizers be administered to these specimens. Results: Empirical evidence indicates that biofertilizers yield more efficient outcomes than their chemical counterparts, all the while preserving the integrity of the environment. Cow dung emerges as a particularly potent biofertilizer, significantly augmenting soil microbial content. The tomato plant—remarkably, the observed growth and yield are substantially greater—demonstrates this effect. Soil health flourishes when jeevamrutham is applied. Fig 1: a tomato plant cultivated via natural farming methods.

**Research methodology**: The experiments were conducted by Vedic Farming methods. It includes seed germination, utilization of fertilizers which are mentioned in Vedas.

**Results and discussion:** Seed germination tests were conducted by Vedic Farming methods. Wheat seeds were taken for experiments.

It involves application of milk, honey and water to soak seeds. Later they were transferred to the soil. The seeds show different percentages of seed germination.

Fig: 1 : Seed germination methods through honey, milk and water

**Table:1: seed germination methods**

| Method | Percentage of seed germination |
|---|---|
| Honey | 70 |
| Milk | 69 |
| Water | 66 |

**Fertilizers :**

The utilization of fertilizers is a very important step in plant growth. There are two types of fertilizers such as Plant based fertilizers And animal based fertilizers. For the experiment, animal based fertilizers were taken. It is cow dung,and is applied to the soil after seed introduction into the soil.

Fig: 2: Cow dung as a fertilizer

Plant growth : regular monitoring was done to identify the plant growth patterns. After 15-20 of incubation period, the plant growth is observed.

Fig : 3: Wheat grass, the growth is observed in the seeds from honey

Fig: 4: Growth observed in the seeds from milk

**Sustainable agriculture methodologies**

(1) are exceedingly crucial for food fortification; moreover, they serve a pivotal role in environmental conservation. These practices neither permit environmental pollution

(2) nor compromise biodiversity—indeed, they enhance it. However, they yield crops in a sustainable manner, facilitating a balance between productivity and ecological integrity.

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# FARMER REGISTRY : A COMPREHENSIVE OVERVIEW

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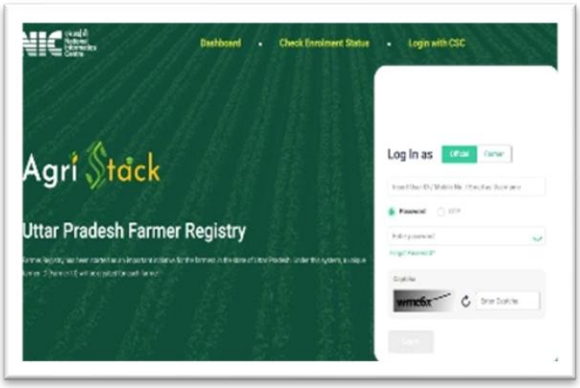
**Abstract**

A farmer registry is a centralized database designed to capture essential information about farmers, their landholdings, crops, and socio-economic conditions. It serves as a critical tool for modernizing agricultural policies, improving service delivery, and ensuring financial inclusion. This article explores the purpose, components, and implementation of farmer registries across different countries, such as India, Kenya, and Brazil, highlighting their role in targeting beneficiaries, data-driven policy making, and promoting sustainability in agriculture. Despite their advantages, challenges such as data accuracy, inclusion of marginalized farmers, and technology gaps hinder their effectiveness. The article proposes solutions, including community participation, digital integration, and policy reforms, to overcome these barriers. A well-maintained farmer registry ensures better resource allocation, transparency, and empowerment of farmers, contributing to sustainable agricultural development and national food security.

**Keyword**: Farmer Registry, Agriculture, Farmer

## Introduction

A farmer registry is a structured database that contains information about farmers, their land holdings, farming activities, and socio-economic conditions. It is a vital tool for implementing targeted agricultural policies, ensuring effective delivery of government schemes, and enabling informed decision-making in the agricultural sector. Over recent years, farmer registries have gained prominence as countries aim to modernize their agricultural practices and support smallholder farmers.




## Purpose of Farmer Registry

The primary aim of a farmer registry is to create a centralized database that captures the details of every farmer within a region. This database is essential for:

a) Identifying Beneficiaries: Ensuring that only eligible farmers receive subsidies, insurance, and financial aid.
b) Data-Driven Policy Making: Providing policymakers with accurate data to design schemes tailored to the needs of farmers.

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c) Improving Service Delivery: Streamlining the distribution of agricultural inputs like seeds, fertilizers, and equipment.
d) Financial Inclusion: Assisting farmers in accessing credit, crop insurance, and other financial services.
e) Monitoring Agricultural Trends: Facilitating data analysis to monitor trends such as crop patterns, productivity, and land use.

**Components of a Farmer Registry**

a) **Farmer Details:** Personal information such as name, age, gender, and contact details.
b) **Land Records**: Information on land ownership, size, location, and soil types
c) **Crops Grown:** Types of crops cultivated, cropping patterns, and seasonal activities.
d) **Livestock** Details: Number and types of livestock owned by the farmer.
e) **Access to Resources:** Details about access to irrigation, credit, and government schemes.
f) **Socio-Economic Status**: Income levels, dependency on agriculture, and level of education.


**Implementation in Different Countries**

**India**: The "PM-Kisan" initiative maintains a farmer registry for direct income support. Digital land records have been integrated into the system, enhancing transparency and efficiency.

**Kenya**: Kenya's "E-voucher" system for subsidized fertilizers relies on a national farmer registry.

**Brazil**: Brazil's Rural Environmental Registry links environmental compliance with agricultural practices, helping in sustainable land management.

**Challenges in Farmer Registries**

Despite their benefits, farmer registries face several challenges:

a. **Data Accuracy:** Ensuring the validity of data, especially in regions with informal land ownership systems.
b. **Inclusion**: Capturing marginalized farmers, tenant farmers, and women farmers who often lack formal records.
c. **Technology Gaps:** Limited access to digital technology in rural areas can hinder data collection.
d. **Maintenance**: Updating the database regularly to reflect changes in land ownership or cropping patterns.

**Solutions to Address Challenges**

a. **Community Participation:** Engaging local bodies and farmer organizations in data collection and validation.
b. **Digital Integration:** Using satellite imagery, GPS, and blockchain to ensure accuracy and transparency.

c. **Capacity Building:** Training government officials and farmers on the use and benefits of digital platforms.
d. **Policy Reforms**: Simplifying land registration processes to ensure formal documentation of land ownership.

**Benefits of Farmer Registry**

a. **Better Resource Allocation:** Ensures that resources are allocated to those who need them the most.
b. **Increased Farmer Empowerment:** Access to information, credit, and government schemes can significantly improve farmers' livelihoods.
c. **Transparency**: Reduces corruption and inefficiencies in the distribution of subsidies and benefits.
d. **Sustainability**: Enables monitoring and promotion of sustainable agricultural practices.

**Conclusion**

A robust farmer registry is indispensable for modern agriculture. By addressing challenges through innovative solutions and inclusive practices, farmer registries can transform the agricultural sector. Governments and stakeholders must work together to ensure that farmer registries are comprehensive, up-to-date, and inclusive. This will not only empower farmers but also contribute to national food security and sustainable agricultural development.

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# ENHANCING MICROBIAL SAFETY OF FRUITS AND VEGETABLES THROUGH BIO-COATING TECHNOLOGIES

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## Introduction

Over the past 20 years, India's consumption of fresh fruits and vegetables has climbed by over 30%. Due to their high nutritious content of vitamins (B, C, and K), minerals (calcium, potassium, and magnesium), and dietary fibre, fresh fruits and vegetables are vital to human nutrition. In addition to offering a nutritious and well-balanced diet, fresh produce can help avoid chronic illnesses like cancer, heart disease, diabetes, obesity, and a number of micronutrient deficiencies, particularly in developing nations. The supply and production of fruits and vegetables vary depending on the demands of the general population. When there is an excess of perishable or semi-perishable fresh fruits or vegetables, it is crucial to store and preserve them to guarantee a steady supply of food. Some fruits and vegetables cannot be cultivated in all soils and climates, therefore preserving them will help with international trade. Various preservation techniques can postpone the ripening and ageing process after harvest, preserving the food's flavour and quality and prolonging the out-of-season food's sale/consumption ratio. A wide range of products are made available on the market by preservation, and food prices can also be shown to stabilise when supply and demand are balanced. In general, fresh fruit and vegetable preservation involves handling and treating them to prevent or delay deterioration or spoiling (microbial and enzymatic decomposition, nutrient loss, flavour loss, texture change, and contamination by microorganisms) while extending the food's shelf life. Fresh fruit and vegetable consumption is rising worldwide, but this is seriously threatened by a rise in microbial contamination. However, there is a lack of current information regarding the sources, routes, and epidemiology of microbial contamination in fruits and vegetables. Technologies for bio-coating have enormous potential for the future of food preservation since they provide a healthier and more sustainable means of preserving fruits and vegetables for longer. Furthermore, because bio-coatings eliminate the need for packaging materials made of plastic, they present an alluring alternative that minimises waste and its negative effects on the environment. Considerations like scalability, cost-effectiveness, and regulatory issues are crucial when deploying bio-coatings for commercial purposes.

## Understanding Microbial Contamination:

For the majority of fruits and vegetables, microbial contamination has emerged as a primary cause of sensory quality shelf-life failure. This is followed by surface discolouration (such as pinking of cut lettuce, browning of cut potatoes, greying and browning with processed pineapple, and grey discolouration with cabbage), water-soaked appearance or translucency (such as cut watermelon, papaya, honeydew, and tomatoes), moisture loss (such as "baby" carrots and celery sticks), flavour changes (like cut kiwifruit), and texture changes (such as processed strawberry, grated celery, kiwifruit, and papaya). One primary or sole objective criterion for determining the shelf life of fresh-cut products is microbial spoilage, which includes the formation of off-flavour (e.g., fermented aroma with cut lettuce, sour taste with cantaloupe and bell pepper), slimy surfaces (e.g., "baby" carrots), wetness and soft rot (e.g., cut bell pepper), discolouration (e.g., apple wedges), and visual microbial growth/colonies (e.g., apple wedges, cantaloupe chunks, and cored pineapple) (Sapers, Miller, Pilizota, *et al*., 2001). Fruits and vegetables can decay due to a variety of bacteria and fungi. Bacteria such as *Bacillus*, *Enterobacter*, *Pseudomonas*, *Staphylococcus*, *Streptococcus*, and others typically contaminate fruits and vegetables. *Salmonella*, *Bacillus*, *Staphylococcus*, *Xanthomonas*, *Streptococcus*, *Pseudomonas sp*., *Coccus*, *E. coli*, *Aeromonas* and *Clostridium* are the primary pathogenic bacteria linked to fruit and vegetable deterioration. Fungi such as *Yeast*, *Penicillium*, *Rhizopus*, and *Mucor* are linked to the deterioration of fruits and vegetables. (Smith *et al*., 1997).

**Plant Extract Coatings: A New Concept to Prevent the Microbial Contamination:**
Herbal bio coating is a new method in the food sector. It is manufactured from plants or a combination of bio coatings and herbs. The most popular herbs used in bio coatings include aloe vera gel, neem, lemon grass, rosemary, tulsi, and turmeric. Herbs have antimicrobial properties and contain vitamins, antioxidants, and vital minerals. Aloe vera gel has recently gained popularity as a coating for fruits and vegetables due to its antimicrobial properties, it helps minimise moisture and water loss. Ginger essential oil, clove bud oil, turmeric neem extract, mint oil, and other essential oils and extracts are utilised in the bio coating of fruits and vegetables. Herbs are a natural source of vitamins, minerals, and antioxidants that are helpful to health and can be used as nutraceuticals or medicines. (Martinez-romero *et al*., 2006)

**Bio Coating as Antimicrobial Solution:**
Bio-coatings can be enhanced with important nutrients, vitamins, or bioactive substances, increasing the nutritional value of fresh fruits and vegetables. These nutrients can be sourced from natural sources or encapsulated in the bio-coating substance, ensuring controlled release and long-term preservation. To guard against spoilage-causing microbes, coating compositions may include natural antimicrobial substances like plant extracts or essential oils (EOs). This reduces the chance of microbial contamination and deterioration, allowing the packaged fruits and vegetables to remain fresh and high-quality for longer periods of time. Essential oil-based bio-coatings can have a considerable impact on sensory qualities since they include volatile molecules that can mask the original flavour of the treated fresh fruit or vegetable. Alternatives to traditional methods could include combining multiple preservation systems or using an essential oil that is suitable with certain types of food. Bio-coatings can assist decrease moisture loss and microbiological growth, extending the product's shelf life. Bio-coatings can aid to maintain the appearance, texture, and flavour of vegetables during storage and transportation. This can be especially useful for high-value produce like berries, tomatoes, and citrus fruits. Bio-coatings can help to maintain the nutritional value of produce, such as vitamins and antioxidants, by slowing oxidation and deterioration.

**Methods to Prepare Bio Coatings:**
The coating material can be applied in its pure form or mixed with other ingredients such as antioxidants, preservatives, or antimicrobial agents, thus enhancing its effectiveness. There are different methods to prepare the bio coating. These are- a) Nanoencapsulation b) Microemulsion Formulation c) Microspinning (Electrospinning) d) Melt Extrusion e) Coacervation f) Phase Inversion Method.

Natural preservatives such as essential oils, when supplemented with nanoencapsulation and nanoemulsions, provide better stability and efficacy by suppressing microbial development, minimising spoiling, and prolonging the shelf life of fresh fruits and vegetables. These technologies establish protective barriers, resulting in improved surface coverage and adherence. The microemulsion is formed by combining the coating components in a suitable solvent system. Microspinning (Electrospinning) is a versatile technology for creating ultra-thin fibres from a wide range of materials. Nanofibers are created using electrospinning. The Melt Extrusion process involves heating the biopolymer until it melts and then extruding or pressing it into a thin layer. The coacervation process is commonly used to encapsulate active chemicals within a biopolymer covering. The Phase Inversion process is used to create porous coatings. The biopolymer is first dissolved in a solvent, after which a non-solvent is added. (Mahajan *et al*., 2017).

**Methods of Bio Coating Application:**

Different techniques should be used to apply bio coatings on fruits and vegetables. The kind of fresh fruits and vegetables, the coating substance, and the required coating thickness can all influence the coating method selection. To avoid contamination and guarantee the coating's efficacy, the application procedure should be performed in a sanitary environment. To maximise the coating's efficiency, it must also be applied evenly and adhere to the produce's surface correctly. These methods are- a) Dipping b) Brushing c) Extrusion d) Spraying e) Solvent casting.

The dipping method, which involves dipping fruits and vegetables in coating solution for five to thirty seconds, is a popular technique for putting bio coatings to these foods. It is simple to use on most fruits. Although brushing produces outstanding results, bio coating is typically applied to beans and extremely perishable fruits and vegetables like berries and strawberries. The food business also uses three other techniques: solvent casting, extrusion, and spraying. Compared to other methods, the extrusion method is the most effective way to apply bio coatings for industrial purposes since it relies on the thermoplastic characteristics of the coatings. (Raghav *et al*., 2016).

**Advantages & Disadvantages of Bio Coating:**

**7.1 Advantages:**

i. Bio coatings preserve the quality of fruits and vegetables while they are being stored by improving the retention of acids, colour, flavour, and sugar.
ii. Decrease firmness and weight loss. To further improve the produce's safety and shelf life, some bio-coatings might include antimicrobial compounds that prevent the growth of harmful and spoiling microorganisms.

**Disadvantages:**

i. Thick coating can prohibit Oxygen exchange, causes off- flavour development.
ii. Bio coatings have good gas barrier properties which causes anaerobic respiration due to this normal ripening process is disturbed in fruits and vegetables.

**Table 1: Bio-Coatings for Preventing the Microbial Contamination of Fruits and Vegetables**

| Sl. No. | Fruits and Vegetables | Used Bio coating |
|---|---|---|
| 1 | Strawberry | Linseed mucilage extract, Chitosan. Pectin, PVA, Starch, Soy protein, Gluten. Sodium Alginate & Calcium Alginate gel |
| 2 | Cantaloupe | Aloe vera gel. Pectin, Chitosan. |
| 3 | Guava | Cassava starch with Cinnamon essential oil |

| Sl. No. | Fruits and Vegetables | Used Bio coating |
|---|---|---|
| 4 | Apple | Neem oil, Marigold flower extract, Guar gum & Aloe vera. Soybean gum, Paraffin wax, Jojoba oil & Arabic gum. Alginate with Lemongrass essential oil |
| 5 | Mango | Chitosan, Aloe vera. Tapico flour, Sago flour, Soy protein. Chitosan. |
| 6 | Pineapple (Fresh Cut) | Chitosan with Eugenol and Aloe vera, Pectin & Alginate. |
| 7 | Banana | PVA, CMC, Tannin. |
| 8 | Blueberry | Alginate with Pectine, Alginate with Chitosan, CMC, Chitosan |
| 9 | Papaya | Chitosan, Aloe vera, Papaya leaf extract. Carnauba wax |
| 10 | Sapota | Aloe vera juice |
| 11 | Plum | CMC, Pectin. |
| 12 | Green bell pepper | Chitosan with Lemongrass essential oil |
| 13 | Potato, Cucumber | Potato starch, Guar gum, Pea starch. |
| 14 | Cucumber | Gum Arabic Powder. Beeswax, High Methoxy Pectin, Chitosan, Aloe vera. Paraffin wax. Sodium Alginate, Starch, Glucose, Sucrose, Chitosan, Sorbitol, PVA. |
| 15 | Pumpkin, Carrot, Radish, Cantaloupe, Cucumber | Chitosan, calcium salt. |
| 16 | Potato | Chitosan, WPC, Coconut oil. |
| 17 | Tomato | Carnauba wax, Rice starch with Coconut oil and Green tea leaf extract, Aloe vera gel |

(Source: Raghav *et al*., 2016)

**Limitations and Challenges of Bio Coatings to Prevent the Microbial Contamination on Fruits and Vegetables:**

Despite their various advantages, bio-coatings present obstacles that must be solved in order to secure widespread adoption. The high cost of production and raw materials is a key obstacle to their widespread application. Bio-coatings may be more expensive to produce and formulate than conventional coatings, limiting their cost-effectiveness. The industry needs to prioritise the development of more cost-effective manufacturing techniques and procurement strategies for bio-coating materials. Another factor influencing the usage of bio-coatings is their availability. Some places or countries may not have readily available to the raw materials required for these coatings. This lack of accessibility may act as a barrier to their broad use. Strategies must be devised to ensure that these materials can be procured or substituted locally, allowing them to be used in a variety of settings worldwide. They should also regulate moisture content while maintaining the appearance of the fruits and vegetables. They must be inexpensive, readily available, uniform, stable during production and storage, non-sticky when handling fruits and vegetables, contain antimicrobial and antioxidant agents, have good surface adhesion, not alter the fruits' and vegetables' flavour, texture, or aroma, maintain a desired moisture content by regulating water migration in the fruits and vegetables, and not alter the fruits' and vegetables' appearance. (Ayush *et al*., 2022).

**Conclusion and Future Prospectives:**

A novel and eco-friendly method of maintaining the freshness of fruits and vegetables is offered by Bio Coatings. The products' shelf life is increased by these eco-friendly fixes. Bio-coatings have the potential to significantly reduce foodborne illnesses, a major global concern, by improving food safety. Bio Coatings prolong shelf life, slow down the ripening process, minimise moisture and water loss, and stop microbes from growing, especially on fresh produce. Herbal bio coating is a recently introduced concept in the field of bio coating. It improves outcomes and has health advantages. Fruits and vegetables with a herbal bio coating are nutrient-dense and medicinal. We anticipate that bio-coating technologies combined with intelligent and active packaging solutions will continue to advance. These could contain markers of ripeness or freshness, or even the gradual release of antimicrobial chemicals. Bio-coatings that preserve fruits and vegetables and improve their nutritional value may also be developed in the future. For these technologies to be widely used, they must be scalable commercially while being cost-effective. Our ongoing search for sustainable solutions in the food business is demonstrated by the investigation and application of bio-coatings, which reflects our increasing environmental consciousness and responsibility. Bio-coatings are at the forefront of new, sustainable, and efficient methods to stop microbial contamination of fruits and vegetables, which is crucial given the constant problem of feeding the world's growing population.

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# *Entada Pursaetha* DC.: A VALUABLE FOREST GENETIC RESOURCE IN TROPICAL INDIA - CONSERVATION STRATEGIES AND SUSTAINABLE UTILIZATION

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**Abstract**
*Entada pursaetha* DC., a gigantic woody liana, is significant for its large woody pods and seeds, with immense ecological, medicinal, and economic value. Distributed across tropical regions, it thrives along streams and humid forests, aiding biodiversity. Tribal communities utilize it as food, medicine, and income through its saponin-rich seeds used in the soap industry. Despite its benefits, *E. pursaetha* is endangered due to habitat loss and overexploitation. Studies reveal effective seed germination treatments, such as hot water, mechanical scarification, and chemical scarification, are essential for conservation. Sustainable utilization and habitat preservation are critical to securing its ecological role and community reliance.

**Keywords**: *Entada pursaetha* DC., Forest genetic resource, Conservation, Sustainable utilization, and Ethnobotany

**Introduction**
*Entada pursaetha,* commonly referred to as Elephant creeper, is a substantial woody liana classified within the family Fabaceae. This species is distinguished by its enormous woody pods, which can attain lengths ranging from 90 to 150 centimeters and contain between 5 and 30 seeds (Priya and Rao, 2008). The distribution of *E. pursaetha* spans tropical regions, encompassing areas from Africa, India, and China, to the Philippines and northern Australia. In India specifically, this plant is found in the sub-Himalayan tracts across the states of Sikkim and Assam, extending to Bihar and Orissa, as well as in the monsoon forests of the Western and Eastern Ghats, including the Andaman Islands.

Habitually, *E. pursaetha* occupies environments along the banks of rivers and streams within humid forest ecosystems. The entirety of the plant is characterized by a high saponin content, which renders it advantageous for applications in the soap industry. Historically, this species has been utilized by indigenous communities as a tribal pulse, with its semi-ripe seeds being employed as a substitute for coffee. Furthermore, the ethnobotanical significance of *E. pursaetha* is profound, with various tribal groups leveraging it for an array of medicinal applications. Among its uses, the plant is noted for its broad-spectrum therapeutic properties, functioning as both a narcotic and a tonic. It has been employed in traditional practices to address a spectrum of health conditions, including ailments related to the liver, general body pains, respiratory infections, and eye diseases, as well as to alleviate arthritis and paralysis.

Despite its many uses, *E. pursaetha* is currently classified as endangered (Varak and Suryanarayana, 1995, Janardhanan *et al.* 2001, and Jadhav *et al.* 2001). The species faces threats from habitat destruction and overexploitation, leading to a significant population decline. Recent conservation

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efforts have emphasized the importance of preserving the germplasm of *E. pursaetha* due to its ecological, medicinal, and economic significance. There is a growing concern and concerted effort to ensure this valuable species conservation and sustainable use.

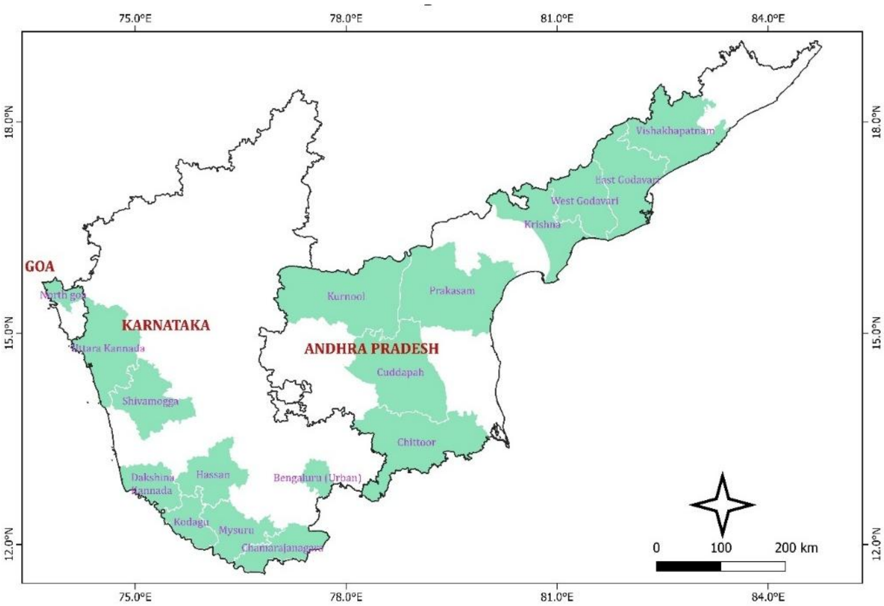
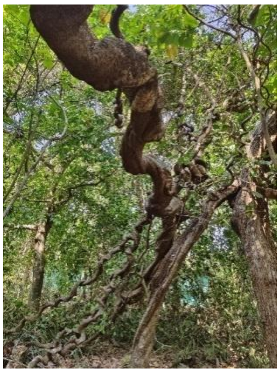



**Fig.1 Distribution of *Entada pursaetha* DC. in the Western and Eastern Ghats of India**

**Botanical description**

It is a gigantic climber with twisted angled stems. Bark brown and fibrous. Leaves dark green, bi-pinnate, leaf-rachis glabrous, grooved, ending in a bifid tendril, pinnae 2-3 pairs, leaflets 3-4 pairs, up to 9*4 cm, ovate-oblong, obtuse of emarginated at the apex. Spikes up to 30 cm long, from the axils of upper leaves or nodes on the leafless branches. Flowers in long axillary pendulous spikes, up to 30 cm long, from the axils of the upper leaves or from the nodes on the leafless branches. Small, polygamous, pale yellow in color. Calyx campanulate, 5-toothed. Petals 5, oblanceolate, free or slightly cohering. Stamens 10, free, shortly connate at base, exserted; anthers tipped with deciduous stalked gland. Ovary is subsessile, with many ovules c. 8 or more; style filiform. Fruit a pod, huge, up to 2m × 15cm size, compressed, woody, 6-15 jointed; joints discoid or square. Breaking down into single-seeded segments, leaving the outer rim (Ramachandra *et al.* 2016).

CLIMBER



Mollem, Goa

FRUIT

Agumbe, Karnataka

SEED

Talakona, Andhra Pradesh

**Fig.2 Morphological characteristics of *Entada pursaetha***

**Ethnobotanical importance**

The seeds of *Entada* possess alexiteric, narcotic, tonic, emetic, anthelmintic, antipyretic, febrifuge, and hemorrhoidal properties. Powdered seeds are given to women post-delivery to alleviate body pain and prevent cold, and they are also used for stomach-ache relief, as a carminative, and as an anodyne. Roasted seeds serve as a tribal pulse, while half-ripe seeds can substitute for coffee. Seed-based concoctions are used as contraceptives, to treat intestinal worms, liver troubles, mumps, and other ailments. The bark is used for treating skin diseases and ulcers, while the stem acts as an emetic. Leaf juice, applied warm with coconut oil or given orally, treats infantile cold. The root paste, mixed with black pepper, is used for epilepsy treatment. The seeds are sold to the soap industry, providing income for tribal communities. In regions like Tirumala and Kolli Hills, seeds are also marketed as fertility stimulants. Additionally, the leaves are used to create soapy solutions for washing bodies and fabrics. This diverse range of uses underscores the economic and medicinal value of *Entada pursaetha*, particularly for tribal communities who rely on it for both health and livelihood (Valaramathi and Raju, 2018).

**Seeds characteristics**

Seeds are flat, round disc-shaped, c. 5 cm in dia., smooth glabrous brown or purple in colour, testa very hard. Can survive lengthy periods of immersion in fresh water and sea water facilitating water dispersal and establishment close to streams and rivers and coastal forests.

**Seed pre-treatments and germination**

Extensive research has investigated various seed pre-treatments that have enhanced germination in *Entada pursaetha*. and overcome the dormancy due to the hard seed coat. Effective methods to overcome seed dormancy include mechanical and chemical scarification. Hot water treatment has proven particularly effective, achieving a 90% germination rate within 15 days of sowing. Conversely, seeds subjected to puncture scarification exhibited a significantly lower germination rate of 20%, with sprouting delayed to 45 days (Vidya *et al.* 2003). Notched seeds soaking in water for 48 hours also enhance the propagation significantly.

Chemical scarification with concentrated sulfuric acid also influences germination. Varying exposure times were tested, with the highest germination percentage observed in seeds treated for 5 minutes. Longer or shorter durations reduced germination success, indicating a precise treatment window for optimal results.

**Conclusion**

Conserving *Entada pursaetha* DC is crucial due to its ecological, medicinal, and economic importance. This large liana, found across tropical regions, is vital for its role in habitats and its use in traditional medicine and the soap industry. Despite its value, *E. pursaetha* is endangered due to habitat destruction and overexploitation. Research on seed pre-treatments, such as hot water and sulfuric acid scarification, highlights the need for effective germination practices. To ensure the species' survival, it is essential to focus on habitat preservation, sustainable use, and reforestation, supporting both biodiversity and the communities that rely on it.

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# ROOTED IN TRADITION: THE RESILIENCE OF CONVENTIONAL AGRICULTURE IN A CHANGING WORLD

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**Abstract**

Agriculture has been at the heart of human civilization for thousands of years, providing food, livelihoods, and economic stability. Conventional farming, which relies on synthetic chemicals, intensive resource use, and large-scale monocultures, has boosted global food production but also brought significant challenges. These include soil degradation, water pollution, loss of biodiversity, and contributions to climate change, alongside economic struggles for small farmers and health risks linked to modern farming practices. Furthermore, the growing disconnect between people and the sources of their food raises questions about the future of sustainable food systems. With the global population expected to reach 9.7 billion by 2050, balancing food security with environmental care has never been more urgent. This article explores the impact of conventional agriculture on the environment, economy, and society, emphasizing the need for innovative and sustainable farming approaches that can protect our planet while ensuring food for future generations.

**Keywords:** Food security, Sustainable agriculture, Food system, heritage, ancestral agriculture

Agriculture has been the cornerstone of human civilization for millennia, underpinning sustenance, livelihoods, and economic development across societies. While technological advancements and innovative farming practices have transformed the agricultural sector, traditional methods of cultivation remain the bedrock of global food production. From expansive rural landscapes to densely populated urban areas, conventional agriculture continues to be pivotal in meeting the nutritional demands of an ever-increasing global population (Sumberg *et al.,* 2022). Conventional farming, often referred to as traditional or industrial agriculture, encompasses practices that rely on synthetic chemical fertilizers, pesticides, herbicides, and other continuous inputs. It frequently incorporates genetically modified organisms (GMOs), concentrated animal feeding operations, intensive tillage, heavy irrigation, and monoculture production systems (Tal,

Image source: New society publishers

2018). While highly resource-intensive and energy-demanding, conventional agriculture is recognized for its substantial productivity. Interestingly, these practices have a relatively recent origin, emerging in the late 19th century and becoming prevalent only after World War II.

Conventional agriculture is frequently overshadowed by emerging approaches such as organic, sustainable, and regenerative farming, which have gained significant attention in recent years. This shift has led to debates about the continued relevance and adaptability of conventional agricultural practices in an era of rapid change. Nonetheless, conventional agriculture remains a robust and evolving sector, demonstrating its ability to integrate new technologies, respond to market demands, and address environmental challenges.

Conventional farming is often juxtaposed with organic agriculture, which emphasizes site-specific strategies that integrate cultural, biological, and mechanical methods to enhance resource cycling, maintain ecological balance, and preserve biodiversity. Unlike conventional methods, organic farming avoids synthetic fertilizers, pesticides, growth regulators, and livestock feed additives, instead utilizing practices such as crop rotation, the application of animal and plant-based fertilizers, manual weeding, and biological pest control (Gabriel *et al.,*2013). Some conventional operations may adopt elements of polyculture or implement aspects of Integrated Pest Management (IPM) to reduce environmental impact.

**Ecological Impacts of Agriculture**

Agriculture significantly influences ecological systems, often leading to adverse environmental effects. Key concerns include soil degradation, water pollution, biodiversity loss, and contributions to climate change.

Declining soil productivity results from factors such as wind and water erosion, soil compaction, reduced organic matter, diminished water retention capacity, and loss of biological activity. In highly irrigated regions, salinization further deteriorates soil quality, while desertification exacerbated by overgrazing continues to threaten arid regions, particularly in Africa.

Image source: Farmers guide

Agricultural practices are major contributors to non-point source water pollution, with runoff containing salts, nitrates, phosphorus, pesticides, and herbicides contaminating groundwater and surface waters. Pesticides from various chemical classes have been widely detected beneath agricultural zones and in rivers, lakes, and oceans. Nutrient runoff leads to eutrophication and the formation of "dead zones," severely affecting aquatic ecosystems, drinking water, and fisheries. Furthermore, excessive reliance on surface and groundwater for irrigation disrupts the hydrological cycle, intensifying water scarcity.

The overuse of pesticides has led to resistance in over 400 insect and mite species and more than 70 fungal pathogens, undermining pest control efforts. Pesticides have also harmed pollinators and beneficial insects, compounding the ecological stress caused by habitat loss due to agricultural expansion, including the conversion of tropical rainforests into pastures. Agriculture's role in global climate change is increasingly recognized. The destruction of forests and native vegetation for farming contributes to elevated atmospheric levels of carbon dioxide and other greenhouse gases. Additionally, soils are now understood to be significant carbon reservoirs, underscoring the need for sustainable land management practices to mitigate climate impacts (Sahm *et al.,* 2013).

**Economic and Social Challenges**

The agricultural sector has historically been characterized by significant federal expenditures, a growing income disparity among farmers, and increasing consolidation of agribusiness industries, which control the manufacturing, processing, and distribution of agricultural products. This concentration has reduced market competition, leaving farmers with limited pricing power and diminishing their share of consumer spending on agricultural goods.

Economic pressures have led to a significant decline in the number of farms, particularly small-scale operations. Between 1987 and 1997, over 155,000 farms ceased operations. For aspiring farmers, the high costs associated with establishing and maintaining a farm present substantial barriers to entry. Furthermore, productive agricultural land continues to be lost to urban and suburban development, with over 30 million acres converted for non-agricultural use since 1970.

**Health Implications**

Modern agricultural practices pose potential health risks to both the general public and farm workers. The widespread use of sub-therapeutic antibiotics in livestock production, as well as the contamination of food and water by pesticides and nitrates, has raised concerns about public health, although the exact risks remain under investigation. Farm workers face heightened health risks due to their increased exposure to these substances.

**Philosophical Reflections**

Agriculture has historically been central to the identity and development of the United States, transitioning from a predominantly agrarian society to one in which less than 2% of the population produces food for the entire nation. This cultural shift raises questions about the feasibility of achieving sustainable and equitable food production when most consumers are disconnected from the natural processes of farming. The decline of rural communities and farmland ownership also prompts reflection on how core American values have evolved and will continue to change.

**Global Population Growth and Food Security**

The world's population is projected to increase significantly, reaching 9.7 billion by 2050 and 11.2 billion by 2100, according to United Nations estimates. This growth is particularly pronounced in developing nations, where rapid industrialization, widespread poverty, political instability, reliance on food imports, and heavy debt burdens intensify concerns about long-term food security. Addressing these challenges is critical to ensuring sustainable global food systems.

**Conclusion**

Agriculture remains fundamental to human civilization, supporting economies, ecosystems, and societies globally. While conventional farming has enhanced food production, it has also introduced challenges, including environmental degradation, resource depletion, economic pressures on small-scale farmers, and health risks. These issues, coupled with a growing disconnect between consumers and food systems, necessitate a transition toward more sustainable practices. With global population growth intensifying food security concerns, sustainable agriculture offers a viable solution by integrating productivity with environmental conservation. By adopting innovative, equitable, and resilient practices, the agricultural sector can address current challenges while ensuring long-term ecological and social sustainability.

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# PROGRESS IN INTERMEDIATE MOISTURE FOODS: INNOVATIONS, OBSTACLES AND FUTURE PATHWAYS

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**Abstract**

The consolidation of dampness control in nourishment preparing is imperative for moving forward the quality, life span and dietary esteem of nourishment things. The sum of dampness display specifically impacts the surface, microbial security and conservation of nourishment. This article analyzes the significance of bound together dampness administration strategies in nourishment generation, emphasizing inventive approaches and advances to fine-tune dampness levels. Procedures like controlled air bundling, moisture-resistant movies and drying out forms are altogether analyzed. These strategies point to play down dampness misfortune, control deterioration and protect key supplements, eventually improving the tangible and utilitarian characteristics of nourishment. Also, the investigate investigates the part of dampness inside the nourishment framework, focusing the need of understanding the connections among water, proteins, carbohydrates and lipids, which influence surface and item consistency. Later advance in nourishment building, counting the creation of cleverly packaging materials and moisture-responsive coatings, is additionally surveyed. These advancements empower real-time dampness following and adjustments, in this way keeping up item quality amid capacity and transport. In addition, the article examines the challenges of keeping up the fitting dampness levels to dodge issues such as nourishment shrinkage, clumping, or microbial development. With the developing buyer inclination for comfort as well as sustenance, the integration of dampness administration frameworks is fundamental for creating useful nourishments that address different dietary necessities. In outline, the appropriation of dampness control strategies is vital for the headway of nourishment science, giving moved forward nourishment quality, security and supportability. Advance examination into dampness conduct in nourishment frameworks and the continuous progression of moisture-sensitive innovations is significant for advancing the teach.

**Keywords :** Water retention capacity, Hygroscopic humidity management, Osmotic drying, Equilibrium moisture content (EMC)

## Introduction

Middle Dampness Nourishments (IMFs) are nourishment things with a water action (aw) by and large between 0.6 and 0.85, which makes a difference to constrain microbial advancement whereas holding dampness and pliability. These items are regularly protected with humectants such as sugar or salt to pull in water and turn away weakening. The thought of Middle Dampness Nourishments (IMFs) came around within the 1950s as a implies to deliver nourishment things that are both shelf-stable and pleasant to eat. Ponders conducted within the 1960s and 1970s, driven by advance in overseeing water movement and the application of humectants, catalyzed their progression. Starting IMFs comprised things such as delicate cheeses and pet nourishments. They got to be outstanding for minimizing the need for refrigeration and moving forward comfort in nourishment capacity.

**Characteristic :** Intermediate Moisture Foods (IMFs) exhibit a range of distinct traits:
Water Movement (aw): IMFs support a water movement extend for the most part falling between 0.6 and 0.85, which is satisfactory to supply item pliability whereas anticipating the larger part of microbial improvement.

Conservation Strategies: They are ordinarily kept up with humectants like sugar, salt, or glycerol that pull in dampness, repressing deterioration and dragging out rack soundness without requiring refrigeration.

Surface and Tastefulness: IMFs keep up a tender and adaptable consistency, progressing mouth feel and buyer endorsement in connection to low-moisture choices.

Rack Soundness: These things appear a long rack life since of controlled dampness substance, which makes them simple to store and transport.

Wholesome Quality: The strategies of conservation utilized in IMFs help in holding dietary esteem and enhance predominant to high-temperature preparing procedures. (Rockland *et al.,*. (1987).

**Importance of Intermediate Moisture Foods (IMFs) in Food Preservation:**
Middle Dampness Nourishments (IMFs) are nourishments that have a dampness substance between 20% and 50%. This dampness level is moo sufficient to anticipate the development of most microorganisms but tall sufficient to protect the food's surface and flavor. IMFs are broadly utilized in nourishment conservation for both their capacity to expand rack life and their comfort.

Microbial Development Control- The decreased dampness substance of IMFs makes an environment that's aloof for microscopic organisms, molds and yeasts. This makes a difference in dragging out rack life without refrigeration. IMFs regularly accomplish this through the combination of moo dampness, tall sugar and/or salt substance, making a "water movement" level that anticipates microbial movement (Bureau *et al.,* 2001).

Supplement Maintenance- IMFs hold the fundamental supplements found in new nourishments such as vitamins and minerals. The conservation handle, which regularly includes drying or halfway parchedness, makes a difference keep up the foodâs wholesome profile. Not at all like conventional conservation strategies like canning, which may corrupt supplements through warm, IMFs protect the judgment of delicate supplements (Olsson *et al.,* 2004).

Amplified Rack Life- Nourishments with middle dampness can be put away for expanded periods without significant decay. Typically especially useful in locals with constrained refrigeration or in crisis nourishment supplies. By stabilizing the food's water movement, IMFs avoid enzymatic responses that ordinarily lead to decay, keeping the nourishment secure for utilization over time (Bureau *et al.,* 2001).

Comfort and Flexibility- IMFs offer convenience in terms of storage, handling and transportation, as they don't require refrigeration. Typically particularly invaluable for ready-to-eat dinners, snacks and travel nourishment items. The conservation prepare regularly keeps up the foodâs unique taste and surface, giving customers with a high-quality item (Olsson *et al.,*., 2004).

**Function of Intermediate Moisture Foods (IMFs) in the Worldwide Food Sector:**

i. Expanded Rack Life: IMFs show decreased water action, restraining microbial development, especially microscopic organisms and molds. This makes them exceedingly reasonable for long-term capacity without the require for additives or refrigeration, guaranteeing their accessibility in inaccessible or resource-limited ranges.
ii. Comfort in Capacity and Transportation: IMFs don't require cold-chain coordinations, lessening costs and complexity in transportation. Their surrounding capacity compatibility makes them perfect for worldwide supply chains, particularly for districts with deficiently refrigeration foundation.
iii. Dietary and Useful Properties: IMFs can be outlined to hold crucial supplements, guaranteeing the conveyance of fundamental vitamins, proteins, and minerals. Their capacity to join bioactive compounds makes them flexible for health-focused items like supper substitutions and braced snacks.
iv. Catering to Customer Requests: Present day customers request comfort, taste, and wellbeing. IMFs address these inclinations by advertising ready-to-eat, flavourful alternatives without relinquishing quality. Illustrations incorporate dried natural products, delicate candies, and certain prepared products.
v. Part in Catastrophe Alleviation and Military Applications: IMFs are crucial in crisis nourishment supplies for disaster-stricken locales and military operations. Their steadiness, lightweight bundling, and caloric thickness give fundamental food beneath challenging conditions.
vi. Bolster for Worldwide Nourishment Security: By amplifying the ease of use of perishable commodities, IMFs contribute to diminishing nourishment wastage and moving forward worldwide nourishment conveyance frameworks. Their application is imperative in handling nourishment shortage in creating countries.
vii. Financial Practicality: Creating IMFs frequently includes lower costs compared to exceedingly perishable items, making them financially invaluable for both producers and customers. Their flexibility permits producers to target different showcase sections. (Rockland *et al.,* (1987).

**Physicochemical Characteristics of Intermediate Moisture Foods (IMFs) and Their Effects:**

**Water action and rack life**- Water movement (aw) plays an basic part within the soundness and life span of Halfway Dampness Nourishments (IMFs). It signifies the amount of free water display in a nourishment thing, influencing both microbial multiplication and chemical forms. For IMFs, the water movement for the most part falls between 0.6 and 0.85, a run that confines the advancement of the lion's share of microbes, molds and yeasts, subsequently amplifying rack life. With a decrease in water action, microbial stability progresses, since there's less accessible free water for microorganisms to thrive. The association between water action and the soundness of organisms is reverse Lower water movement confines the advancement of deterioration microorganisms, while expanded water action advances microbial development. By keeping water movement at an perfect level, IMFs can avoid deterioration and keep up their quality as time goes on. Besides, consolidating humectants such as sugar and salt makes a difference to hold free water and relieve microbial defilement. (Rockland *et al.,*. (1987)).

**Surface and Tangible Properties :** The characteristics and tangible properties of Middle of the road Dampness Nourishments (IMFs) are basic for customer endorsement. IMFs offer a delicate, chewy, or flexible texture, which is significantly acknowledged by buyers because it takes after new nourishment whereas moreover advertising ease of utilize. The moisture level, directed inside a run of 0.6 to 0.85 aw, incorporates a coordinate affect on the mouth-feel, ceasing the nourishment from becoming overly tough or too much soft. Tangible characteristics such as flavor, fragrance and appearance are too critical, as they have to be remain appealing indeed after conservation. Enough directed dampness stops unwelcome changes such as staleness or over-drying. In common, the fitting surface and tangible characteristics ensure that IMFs fulfill consumers' wants for flavor, comfort and quality. (Rockland *et al.,* (1987).

**Dietary Suggestions :** Middle Dampness Nourishments (IMFs) offer different dietary benefits in comparison to other conservation methods. Since IMFs utilize controlled water action rather than seriously warm, they more often than not protect a bigger sum of heat-sensitive supplements, counting vitamins (e.g., vitamin C) and proteins, relative to canned or freeze-dried items. The joining of humectants, such as sugar and salt, helps in protecting dampness whereas keeping dietary esteem intaglio. Besides, IMFs keep up more normal flavors and surfaces, which upgrades the total eating involvement. Then again, elective conservation procedures such as canning or drying may result in supplement debasement, particularly due to hoisted temperatures or drawn out preparing. As a result, IMFs give a agreeable arrangement, defending crucial supplements whereas maintaining nourishment quality. (Fennema, O. R., *et al.,*.).Technological Advances.

**Processing Strategies :** It incorporate moved forward drying procedures strategies such as discuss drying, solidify drying and splash drying, which help in directing water movement for improved conservation. Osmotic lack of hydration has risen in significance because it involves submerging nourishments in a hypertonic arrangement to extricate dampness whereas protecting surface and flavor. The utilize of humectants, fixings like sugar, salt, or glycerol help in dampness maintenance, ruining bacterial development and improving life span. Moreover, antimicrobial operators natural acids and normal extricates are continuously being included to improve rack life and turn away deterioration whereas keeping up flavor and surface (Rockland *et al.,*1987).

**Emerging innovations :** It has impressively made strides the fabricating of IMFs High-Pressure Processing (HPP) utilizes weight instead of warm to drag out rack life whereas keeping up supplements and flavor. Microwave-assisted parchedness quickens drying methods, improving vitality productivity and item quality by minimizing supplement consumption. Nanotechnology applications in dampness administration permit for more exact control of water movement, improving food consistency and life span. These headways help within the advancement of more viable, maintainable and nutrient-retaining IMFs. (Barbosa *et al.,* (2005).

**Smart packing solution :** (IMFs) have driven to the improvement of smart packing solution that move forward quality upkeep. Dynamic bundling utilizes substances that lock in with the nourishment, counting oxygen safeguards or mugginess controllers, to drag out rack life and keep up freshness. Brilliantly bundling, in differentiate, coordinating sensors that track and transfer the condition of the nourishment, counting variables like temperature and stickiness, ensuring perfect capacity and minimizing the chance of deterioration. These headways in bundling help in keeping the specified dampness levels and repressing microbial improvement, driving to upgraded item solidness and security for buyers. (Laufenberg, G., *et al.,* 2007).

**Application**

Middle of the road Dampness Nourishments (IMFs) are utilized over various nourishment categories, each procuring benefits from directed dampness levels. Nibble things such as natural product bars and delicate wafers take advantage of dampness adjust to hold chewiness whereas amplifying rack life. Ready-to-eat (RTE) dishes, like moment soups or rice suppers, keep up surface and taste without refrigeration. Dried natural products such as raisins and apricots protect dampness to stay delicate and consumable, in differentiate to customarily dried things. Meat items like jerky or delicate wieners actualize IMF procedures to improve rack life whereas protecting taste and dietary substance. IMFs in India have experienced a critical rise due to their common sense and expanded rack life, catering to the burgeoning comfort nourishment advertise. With active ways of life in urban zones, IMFs like ready-to-eat suppers, snacks and dried natural products are getting to be more favored. Besides, expanded wellbeing mindfulness has provoked shoppers to look for items with characteristic additives, lower sugars and more adjusted wholesome substance, highlights that IMFs can give. These improvements are moving the development of more beneficial IMFs within the Indian scene, clearing the way for development in flavors and bundling. (Arora, A., *et al.,* (2021).

**Consumer perspective and challenges**

In India Shopper slants towards Halfway Dampness Nourishments (IMFs) are moving towards clean-label items, with a rising crave for straightforwardness and characteristic fixings. Customers are progressively mindful of added substances and additives, inciting brands to convey IMFs that contain basic, recognizable fixings. The intrigued in plant-based IMFs is additionally developing, fueled by wellbeing cognizant and eco-aware shoppers. Utilitarian IMFs, enhanced with probiotics, strands, or vitamins, are picking up footing for their wellbeing preferences. In any case, challenges hold on, counting the need to protect the tactile offer of IMFs whereas tending to these unused requests and overcoming cost affectability within the Indian showcase. (Sharma, S. 2021).

Challenges- Microbial Defilement Hazard- On the off chance that not legitimately handled, IMFs may still harbor pathogens, driving to deterioration or food-borne ailment in spite of moo dampness substance. Disgraceful taking care of amid generation or capacity can cause defilement (Bureau *et al.,*2001).

Capacity and Transportation Issues- Whereas IMFs are less sensitive to temperature, they still require controlled situations to preserve quality and avoid dampness assimilation from sticky conditions. Bundling must be air proof to avoid dampness re-absorption, which may debase quality (Olsson *et al.,* 2004).

Textural Changes Over Time- IMFs can experience undesirable textural changes, such as getting to be as well difficult or as well delicate, depending on dampness levels. This will affect customer worthiness, particularly in nibble nourishments (Olsson *et al.,* 2004).

Fetched of Generation- The method of accomplishing halfway dampness substance regularly requires specialized hardware and methods, driving to higher generation costs. This may restrain the reasonableness of IMFs for a few markets (Bureau *et al.,* 2001).

Constrained Assortment of Reasonable Nourishments- Not all food types are agreeable to IMF handling, restricting the assortment of items accessible in this category. Certain nourishments may lose their flavor or wholesome esteem when got dried out to the proper dampness level (Olsson *et al.,* 2004).

**Sustainability and environmental impact**

**Positive Natural Impacts:**

Decreased Nourishment Squander- IMFs, by amplifying rack life, altogether diminish nourishment squander, a basic issue universally and in India. Amplified capacity capabilities cruel that perishable things, particularly natural products, vegetables and meats, can be protected for longer terms, hence minimizing decay and misfortune (Sharma *et al.,* 2020). This contributes to a diminishment within the generally natural burden related with squander administration.

Lower Vitality Utilization for Storage- IMFs frequently don't require refrigeration, which leads to a diminishment in vitality utilization for capacity. Given the broad vitality deficiencies and tall power costs in numerous country parts of India, this characteristic is especially profitable for small-scale agriculturists and nourishment makers. (Rao *et al.,* 2018).

**Negative Natural Impacts:**

Energy-Intensive Handling- The generation of IMFs regularly includes energy-demanding forms such as drying or halfway lack of hydration. Whereas vitality utilize is lower in capacity, the beginning parchedness forms can devour critical sums of fuel or power, contributing to carbon emanations, especially when fueled by non-renewable vitality sources (Sharma *et al.,* 2020).

Bundling Squander- To guarantee the moo dampness content is kept up, IMFs regularly require bundling that's waterproof and moisture-resistant. This regularly includes the utilize of plastic materials, which can contribute to natural contamination in case not appropriately reused or arranged of, particularly in nations like India with restricted reusing foundation (Rao *et al.,* 2018).

Asset Seriously Crude Materials- The generation of IMFs may lead to over-exploitation of crude materials, especially within the case of water-intensive crops like natural products and vegetables. This could worsen water shortage issues, especially in drought-prone zones (Sharma *et al.,* 2020).

**Future prospects of IMF**

The direction of Middle of the road Dampness Nourishments (IMFs) is expected to be changed by the consolidation of Manufactured Insights (AI) and Web of Things (IoT) innovations. AI-powered prescient models will be crucial in upgrading IMF quality by evaluating factors like dampness levels, surface and supplement conservation, empowering producers to finely tune generation forms. IoT associated sensors will encourage real-time observing of capacity conditions, ensuring ideal quality and minimizing squander. This mechanical movement guarantees to cultivate a more proficient and feasible generation scene, improving the customer encounter whereas cutting costs. Long run of Middle Dampness Nourishments (IMFs) is balanced for the investigation of inventive plant-based humectants. These economical components, such as alginates, pectins and plant sugars, show eco-friendly substitutes to customary engineered humectants, helping within the conservation of nourishment quality and rack life. Such innovations reverberate with the expanding customer request for clean-label and plant-based offerings, boosting the allure of IMFs within the worldwide showcase. (Shukla, S. K., *et al.,* (2021)).

**Conclusion**

The direction of Middle of the road Dampness Nourishments (IMFs) is expected to be changed by the consolidation of Manufactured Insights (AI) and Web of Things (IoT) innovations. AI-powered prescient models will be crucial in upgrading IMF quality by evaluating factors like dampness levels, surface and supplement conservation, empowering producers to finely tune generation forms. IoT associated sensors will encourage real-time observing of capacity conditions, ensuring ideal quality and minimizing squander. This mechanical movement guarantees to cultivate a more proficient and feasible generation scene, improving the customer encounter whereas cutting costs. Long run of Middle Dampness Nourishments (IMFs) is balanced for the investigation of inventive plant-based humectants. These economical components, such as alginates, pectins and plant sugars, show eco-friendly substitutes to customary engineered humectants, helping within the conservation of nourishment quality and rack life. Such innovations reverberate with the expanding customer request for clean-label and plant-based offerings, boosting the allure of IMFs within the worldwide showcase.

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# EXPLORATIVE STUDY ON THE EFFECT OF TANK REHABILITATION PROGRAMME IN PUDUKKOTTAI DISTRICT

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## Abstract

The Tank Rehabilitation Programme (TRP) implemented in Pudukkottai district, Tamil Nadu, aims to address challenges in water resource management and agricultural sustainability. This study explores the multifaceted impacts of the programme, focusing on agricultural productivity, water availability, socio-economic benefits, and environmental rejuvenation. Data collected from field surveys, interviews, and secondary sources reveal significant improvements in irrigation efficiency, crop yields, and community participation. However, challenges such as inadequate maintenance and equitable water distribution persist. This paper highlights key findings and provides recommendations for sustainable management of tank systems.

**Keywords**: Tank rehabilitation, Pudukkottai, irrigation, agricultural productivity, community participation

## Introduction

Traditional tank irrigation systems have been a cornerstone of water management in semi-arid regions of India. In Tamil Nadu, tanks serve as vital resources for agricultural and domestic water needs. However, neglect, encroachments, and environmental changes have led to the degradation of these systems. In response, the Tank Rehabilitation Programme (TRP) was initiated in Pudukkottai district to restore the functionality of these tanks, enhance agricultural productivity, and support rural livelihoods.

This paper investigates the impacts of the TRP in Pudukkottai, examining both successes and persistent challenges. It aims to inform policymakers and stakeholders about strategies to ensure the sustainability of rehabilitated tanks.

## Objectives

- To evaluate the impact of tank rehabilitation on agricultural productivity in Pudukkottai district.
- To assess changes in water availability and usage patterns post-rehabilitation.
- To study the socio-economic benefits of the programme for local communities.
- To identify challenges and propose recommendations for sustainable tank management.

## Methodology

The study adopts a mixed-method approach involving both quantitative and qualitative data:

**Study Area**: Pudukkottai district, Tamil Nadu, known for its reliance on tank irrigation. Ten rehabilitated tanks were selected for the study.

**Data Collection**: **Primary Data**: Field surveys, structured interviews with farmers, and focus group discussions with Water User Associations (WUAs). **Secondary Data**: Government reports, academic publications, and GIS data on tank catchment areas.

**Sampling**: Stratified random sampling was used to ensure representation from upstream, midstream, and downstream areas.

**Data Analysis**: Statistical tools were employed for quantitative analysis, while qualitative data were coded thematically.

## Results and Discussion

### Agricultural Productivity

Crop yields for paddy, groundnut, and pulses increased by 30–40% post-rehabilitation. Farmers reported reduced dependency on bore wells, leading to lower irrigation costs. Improved water availability extended the cropping season, enabling double-cropping in some areas.

### Water Availability and Distribution

Groundwater recharge improved significantly, with levels rising by 1.8 meters on average near rehabilitated tanks. Enhanced storage capacity of tanks reduced water stress during critical growth periods. However, water distribution inequalities were observed, particularly in tail-end regions.

### Socio-Economic Benefits

Household incomes increased by 20–25% due to higher agricultural outputs. Employment opportunities grew, especially during rehabilitation activities and post-harvest operations. Women's participation in WUAs remained limited, highlighting gender disparities.

### Environmental Impact

Desilting of tanks improved water quality and restored biodiversity in catchment areas. Vegetative bunds reduced soil erosion, enhancing land fertility. Community-led afforestation initiatives supported ecological rejuvenation.

### Challenges Identified

Lack of regular maintenance led to silt accumulation in some tanks within two years. Conflicts over water sharing persisted due to the absence of effective governance mechanisms. Insufficient training for WUAs limited their capacity for sustainable management.

## Recommendations

1. **Capacity Building for WUAs**: Provide training on equitable water distribution and conflict resolution. Encourage greater participation from women and marginalized groups.
2. **Sustainable Maintenance Practices**: Establish a dedicated fund for periodic tank desilting and infrastructure repairs. Promote community-led maintenance models.
3. **Policy Interventions**: Strengthen legal frameworks to prevent encroachments. Introduce incentives for farmers practicing sustainable water use.
4. **Technological Integration**: Utilize GIS and IoT for real-time monitoring of tank systems. Develop mobile apps to enhance coordination among WUAs and local authorities.

## Conclusion

The Tank Rehabilitation Programme in Pudukkottai district has delivered substantial benefits in terms of agricultural productivity, water availability, and socio-economic development. However, ensuring the long-term sustainability of rehabilitated tanks requires addressing challenges related to maintenance, governance, and inclusivity. By adopting an integrated approach that combines technological innovation, community participation, and policy support, the full potential of traditional tank systems can be realized.

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# POLYAMINES: THEIR ROLE AND MODE OF ACTION IN ALLEVIATING HEAT STRESS IN CROP PLANTS

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**Abstract**

Many global climatic models predicted that, increased variability and recurrent incidence of heat stress episodes in future climate will deleteriously affect crop productivity. Finding different ways to overcome heat stress in plants is in need of hour. Among these strategies, seed priming and exogenous application of polyamines show promise in enhancing plant resilience. Polyamines, includes putrescine, spermidine, and spermine, play crucial role in plant tolerance under unfavorable conditions. They help maintain membrane integrity, activate antioxidant defense systems, and regulate reactive oxygen species. The efficiency of polyamine application in combating heat stress requires further exploration. Understanding the mode of action and optimizing application methods and concentrations are crucial for utilizing polyamines effectively in mitigating heat stress and improving crop productivity.

## Introduction

Climate change poses a significant threat to crop productivity, leading to financial losses for countries due to abiotic stresses. Rising temperatures, primarily caused by climate change, have a detrimental impact on plant growth and development. Heat stress damages cellular structures, disrupts photosynthesis, and increases water demand, putting plants at risk. To mitigate the impact of heat stress, various strategies can be employed, including breeding thermo-tolerant varieties, developing transgenic varieties, adjusting sowing dates, and applying chemicals through seed priming or external application. Seed priming involves initiating germination-related activities and improving germination potential through processes such as respiration, endosperm weakening, and gene transcription and translation. Priming also induces abiotic stress responses, leading to the accumulation of stress-related proteins and the development of cross-tolerance. Exogenous application of chemicals, such as polyamines, can help maintain membrane integrity and activate antioxidant defense systems, reducing high-temperature stress. Polyamines, which increase during abiotic stress, have been shown to enhance stress tolerance by regulating reactive oxygen species and antioxidant systems (Yang *et al*., 2007; Liu *et al*., 2015). Studies have demonstrated that the external application of putrescine can induce thermo-tolerance in wheat. We discussed role of polyamines and their mode of action in alleviating heat stress in this article.

**Polyamines, types and their location** Polyamines are small organic compounds containing nitrogenous bases and amino groups. They possess significant biological activity in normal developmental processes and play essential roles in plant tolerance to unfavorable conditions (Thomas *et al*., 2020). The three primary polyamines that have garnered considerable attention are putrescine (Put), spermidine (Spd), and spermine (Spm). While these three amines are often considered together, they exhibit varying degrees of biological effects. Studies involving cytochemistry and subcellular fractionation have indicated that the cell wall and vacuole serve as major reservoirs for polyamines in plants. Additionally, polyamines have been identified in the cytoplasm, nucleus, plasma membrane, mitochondria, and chloroplasts (Slocum *et al*., 1991). Polyamines play various roles in plants which are important in normal plant functioning. They have structural and regulatory role in plants including protection of cell DNA from ROS and alkylating agents. Polyamines regulate $Ca^{2+}$, $Na^{+}$, and $K^{+}$ homeostasis by controlling ion channels. They play important role in cell growth and development and during stress condition.

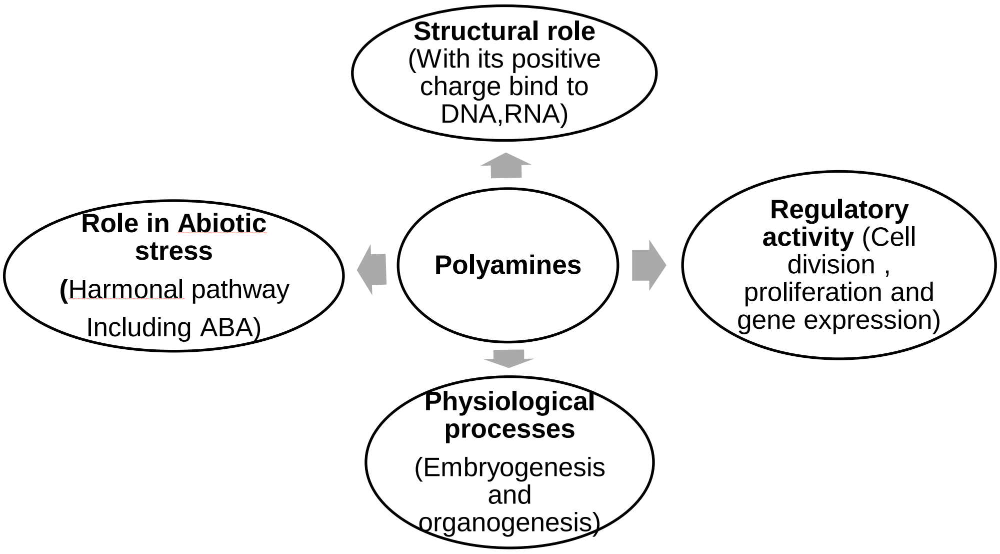


**Fig 1: Multiple roles played by polyamines in plants Kusano *et al*., 2008**

The protective mechanisms of plant cells conferred by polyamines under stress conditions vary depending on the specific conditions. A comprehensive review conducted by Shahid *et al*., (2018) discusses these mechanisms in detail. To provide a concise summary, Table 1 presents a tabulated form outlining the various modes of protection offered by polyamines under different stress conditions.

**Table 1: Mode of action of Polyamines in alleviating heat stress (Shahid *et al*., 2018)**

| Mechanism of action | References |
|---|---|
| They interact with melatonin to enhance the efficiency of the antioxidant system and activate the ascorbate-glutathione cycle | Jahan *et al*., 2019 |
| Polyamine conjugate molecules are instrumental in scavenging harmful reactive oxygen species and enhancing the activity of antioxidant enzymes. | Shahid *et al*., 2018 |
| Polyamines, specifically putrescine (Put), are involved in hormonal regulation and stress signaling in plants, aiding in the response to oxidative stress | Pal *et al*., 2018 |
| Soluble protein content of leaves and reduce the relative conductivity and malondialdehyde (MDA) content | Zhang *et al*., 2010 |
| Protective mechanisms of polyamines involve the formation of a complex with phospholipids and $Fe^{2+}$ to prevent $Fe^{2+}$ auto-oxidation, thereby shielding membranes from oxidative damage. | Velikova *et al*., 2000 |
| Spermine enhances heat shock proteins (HSPs) and heat shock transcription factors | Sagor *et al*., 2013 |

**Conclusion**

Considerable research has been conducted on the use of polyamines to mitigate the impact of drought and cold stress. However, there is a scarcity of studies investigating the effectiveness of polyamine application in combating heat stress in crop plants. It is important to explore the potential of applying polyamines in the right concentrations and using appropriate methods to enhance plant resilience against heat stress.

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# SHIDAL: TRADITIONAL FERMENTATION TECHNIQUES AND NUTRITIONAL BENEFITS OF NORTHEAST INDIA'S ICONIC FISH PRODUCT

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**Abstract**
Fermented foods are an integral part of global culinary practices and offer significant nutritional benefits due to their rich content of beneficial microorganisms. These foods, ranging from dairy products to fermented fish, enhance dietary diversity and are linked to numerous health benefits, such as improved digestion and anti-inflammatory effects. Fish fermentation, particularly the production of Shidal in Northeast India, highlights the region's unique traditional methods and cultural heritage. Prepared from small carps, Shidal undergoes a long fermentation process that enriches its nutritional profile, including high levels of essential omega-3 fatty acids (EPA and DHA), bioactive peptides, and antioxidants. These compounds contribute to various health-promoting properties, such as antihypertensive, antimicrobial, and immunomodulatory effects. However, the presence of biogenic amines and potential pathogens in fermented fish products calls for regulated quality control to maximize their health benefits safely. This paper explores the preparation, health effects, and cultural value of Shidal in Northeast Indian communities.

**Keywords:** Fermentation, Shidal, omega-3 fatty acids, bioactive peptides, Northeast India

**Introduction**
Fermented foods hold significant importance in global culinary traditions and human nutrition due to their ability to enhance the flavors, aromas, and textures of food while preserving vital nutrients. They are not only a source of dietary diversity but also contribute to health benefits through the presence of beneficial microorganisms. These foods include a wide array of products such as alcoholic beverages, vinegar, pickled vegetables, sausages, cheeses, yoghurts, vegetable protein sauces, and leavened breads. The fermentation process involves the action of edible microorganisms, whose enzymes—particularly amylases, proteases, and lipases—hydrolyze polysaccharides, proteins, and lipids into non-toxic compounds that are often more palatable and nutritious than their raw counterparts (Steinkraus, 1997).

Among fermented products, fish holds a unique place, providing distinct sensory characteristics that appeal to specific consumer preferences. The transformation of fish into fermented products results from the biochemical activities of microorganisms and enzymes present in fish muscle tissue, leading to the development of unique flavors, aromas, and textures (Beddows, 1998). This is particularly evident in regions where fish is a staple, and traditional fermentation practices have been developed over centuries.

Northeast India, geographically situated between latitudes 21°50' and 29°34'N and longitudes 85°34' and 97°50'E, comprises seven states: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura. This region covers approximately 8% of India's total geographic area (Das *et al*., 2016). The cultural diversity within Northeast India is reflected in its population, where various tribal communities constitute about 75% of the local demographic (Das and Deka, 2012). Each community possesses distinct languages, lifestyles, and food habits, leading to the production of a variety of fermented foods and beverages. These region-specific products often utilize unique substrates and traditional manufacturing techniques, with the term "fermentation" derived from the Latin verb *fervere*, meaning "to boil" (Das and Deka, 2012).

Shidal is a salt-free, semi-fermented solid fish product from Northeast India, renowned for its unique aroma and taste. This high-quality product is characterized by a dark reddish-brown color and is made exclusively from small carps known locally as puthi (Puntius spp.). It is typically consumed after extensive cooking, frequently enjoyed as Shidal-chutney, a beloved dish among many tribal and non-tribal communities in the area (Muzaddadi and Basu, 2003). The fish is prepared and cooked in earthen pots, called mutka, where it is also stored until it is sold. Variations of Shidal can be found in several Northeastern states, including shidal and hidal in Assam, sepaa and shidal in Tripura, and ngari in Manipur, along with similar products in Nagaland and Arunachal Pradesh. In Bangladesh, comparable products are referred to as chepa shutki (Mansur *et al*., 2000; Nayeem *et al*., 2010). These semi-fermented fish products maintain the original shape and size of the raw fish used, adding to their appeal as a condiment served with rice.

**Preparation of Shidal**

**Step 1: Selection and Preparation of Fish**

The process begins with the careful selection of fish, primarily from the Puntius species. These fish are first dried and then hand-sorted to ensure uniformity in size and quality. Only those fish that are completely free from infestation and possess the desired flesh characteristics are chosen. The selected fish are then sun-dried to remove excess moisture, which is critical for the fermentation process.

**Step 2: Washing and Soaking**

After drying, the fish undergo a thorough washing process. This involves soaking them in running water for a duration of 10 to 15 minutes. This step serves multiple purposes: it rehydrates the fish slightly, making them more pliable, and it also helps to remove any residual impurities from the drying process, enhancing the overall cleanliness and taste of the product.

**Step 3: Overnight Drying**

Following the washing, the fish are laid out on bamboo mats to dry overnight at room temperature. This additional drying phase is essential as it further reduces the moisture content, allowing for optimal fermentation conditions. The use of bamboo mats also facilitates air circulation, ensuring even drying and preventing any mold formation.

**Step 4: Packing in Fermenting Containers**
Once adequately dried, the fish are compactly packed into specially prepared fermenting containers known as matkas. Before filling, these matkas are smeared on the inside with oil (typically mustard oil), which acts as a protective layer against moisture and enhances the flavor of the fish during fermentation. The fish are layered tightly within the container, reaching up to the neck to minimize air exposure, which is crucial for the fermentation process.

**Step 5: Sealing the Containers**
After the fish are packed, the mouth of the matka is sealed with a cover paste made from dried fish. This paste is applied generously to create an airtight seal, preventing unwanted contaminants from entering the container. To further ensure an effective seal, the cover is wrapped with paper or banana leaves, adding another layer of protection. The containers are then left undisturbed for a period of 3 to 4 days. This initial resting phase allows the natural fermentation process to begin, as microorganisms present in the fish and the environment start to act on the fish proteins.

**Step 6: Fermentation**
After the initial sealing period, the cover paste is removed and replaced with a thick layer of clay, which acts as a barrier against external elements while allowing the fermentation process to continue. The matkas are then stored in a cool, ventilated area where they can ferment for a duration of 3 to 5 months at ambient temperature. During this time, the fish undergoes a biochemical transformation, with the activity of various microorganisms breaking down proteins, fats, and carbohydrates into simpler, flavorful compounds. This long fermentation period is crucial for developing the characteristic aroma, flavor, and texture that shidal is renowned for.

Fig.1. Shidhal Preparation. (Muzaddadi and Basu, 2003)

**Finalization and Enjoyment**

Once the fermentation process is complete, the shidal is ready for consumption. The final step involves carefully removing the clay seal and the cover paste. The shidal, with its unique taste and aroma, is then packaged and made available for culinary use, often enjoyed as a condiment or a key ingredient in various traditional dishes. This entire preparation process highlights the rich cultural heritage of the Northeast Indian tribes and their intricate knowledge of fermentation techniques, resulting in a product that is both nutritious and flavorful.

**Nutritional composition of shidal**

| Parameters | Quantity (%) |
|---|---|
| Moisture | 18.84 |
| Ash | 16.3 |
| Lipid | 16.73 |
| Protein | 38.93 |
| Non-protein nitrogen | 7.38 |

(Majumdar *et al*., 2009)

**Health Benefits and Safety Considerations of Fermented Fish Products**

Fermented fish products offer several health benefits due to their unique nutrient profile and bioactive compounds. The fermentation process enhances the organoleptic qualities and increases mineral bioavailability, making the nutrients more accessible to the body. Fermented fish is particularly rich in EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), omega-3 fatty acids known for their role in reducing inflammation and potentially alleviating symptoms of conditions like atopic dermatitis. Additionally, these products contain natural antioxidants and bioactive peptides, which have been shown to exhibit antioxidant, antimicrobial, antihypertensive, and immunomodulatory effects.

The bioactive peptides derived from fermented fish may contribute to health by countering oxidative stress, a factor implicated in aging and carcinogenesis. Studies on fermented fish sauces, such as those made from Labeo rohita, indicate high levels of antioxidant activity. Moreover, these peptides may serve various functions, including acting as ACE inhibitors (beneficial for hypertension), anticancer agents, and even as protective agents against certain pathogens.

However, fermented fish products can also pose health risks if not properly regulated. Biogenic amines (BAs), nitrogenous compounds formed during fermentation, can cause adverse reactions such as headaches, nausea, and allergic responses, particularly in sensitive individuals. High levels of histamine and tyramine are common concerns in some fermented fish products, necessitating careful monitoring. Additionally, pathogens like *Clostridium botulinum, Salmonella, and Listeria have been identified in some products, underscoring the importance of strict quality control standards to ensure safety.

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# NATURAL FARMING THROUGH CROP RESIDUE RECYCLING FOR NURTURING SOIL HEALTH

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**Abstract**

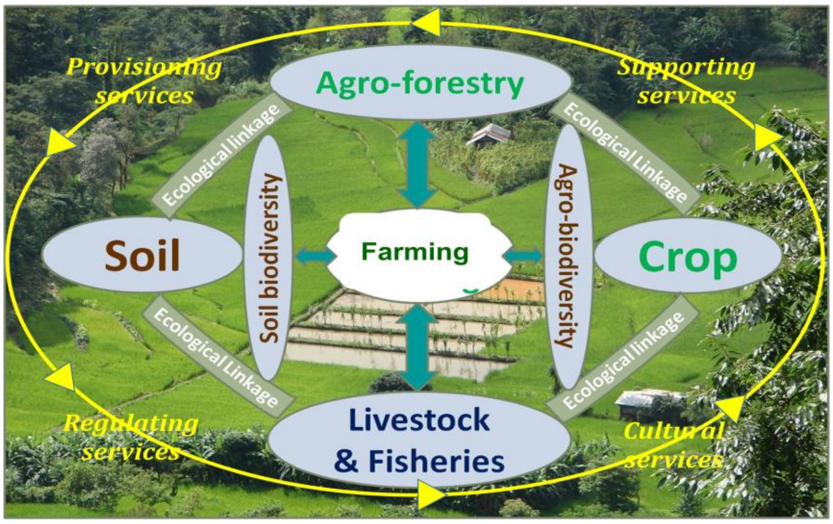
The inherent fertility of the soil is reducing and it is becoming barren due to the enormous use of synthetic fertilizers, plant protection chemicals, and growth regulators. The main reason behind all these problems is increasing human population. Due to increase in population, demand for food is increasing but the natural resources for production like land area is limited and fixed so from the fixed area the production is to be increased by improve the productivity. To save the agricultural production system and restore the fertility of the soil, natural farming is one of the best remedies. Natural farming is a chemical free traditional farming based in sound agro-ecology with a focus on diversified farming based on crops, trees and livestock, allowing the optimum use of functional biodiversity. Crop residues are, in general, plant parts that remain in the field after crops have been harvested, threshed, or processed. It is a crucial source of carbon (C) and plant nutrients, can be a boon for sustainable agriculture and reinvesting back into the soil will keep soils against soil erosion, improve water conservation, enhance soil organic carbon and recycle nutrients. The benefit of recycling crop wastes is that they can be used to make valuable products that help crops achieve their nutrient requirements. Residues provide potassium (K) as well as other nutrient element that may not be available in inorganic fertilizers. Use of crop residue and green manuring plays an important role in growth, development and yield attributing parameter of crop.

**Keywords:** Natural Farming, Crop residue recycling, Soil health, Plant nutrients and Sustainable crop production.

## Introduction:

Natural farming is a system where the laws of nature are applied to agricultural practices. Ecological Farming combines modern science and innovation with respect to nature and biodiversity. Ecological farming approach established by *Masanobu Fukuoka* (1913-2008). It ensures healthy farming and healthy food. It protects the soil, the water and the climate. It builds on natural or ecological processes that exist in or around farms. The goal of natural farming is to contribute to the enhancement of sustainability. According to natural farming principle plant get 98% of their supply of nutrients from the air, water, and sunlight and the remaining 2% can be fulfilled by good quality of soil with plenty of friendly microorganism (Just like in forest and natural system). It also enhances farmers' income while delivering many other benefits, such as restoration of soil fertility and environmental health, and reducing greenhouse gas emissions.

The concept of healthy soil is receiving more attention today. A healthy soil will respond to management, resist deterioration, preserve soil biotic habitat, encourage and sustain root growth, and release water and nutrients as needed. Generally, there are four basic principals involved in soil health: limited soil disturbance; soil covered with residue or cover crops; diversity; and keeping a living root as much of the year as possible. An additional fifth principle is to bring grazing livestock back into your system.




**ECOLOGICAL PERSPECTIVES**

Crop residues, in general are parts of the plants left in the field after crops have been harvested (E.g. Straw stubble, stover, haulms, leaves, etc.) and threshed/process (E.g. Groundnut husk, oil cakes, empty Cobs of maize, Bajra, etc.). They are non-economical plant part left and the field after harvest that is discarded during crop processing.The recycling of crop residues has the advantage of converting the surplus farm waste into useful product for meeting nutrient requirement of crops. It also maintains the soil physical and chemical condition and improves the overall ecological balance of the crop production system. Burning of crop residue, which not only lead to loss of huge biomass but also cause environmental pollution a large amount of rice residue is annually produced in the rice growing countries. Agricultural waste is composed of organic wastes (animal excreta in the form of slurries and farm yard manures, soiled water and silage effluent). It includes natural waste, animal waste and plant waste. To deal with potential challenges of crop residue recycling we have to Stop using high input external fertilizers, use on farm compost and green manure crop instead.

**Field/Harvest crop residue**

**Processed residue**

**Principles of Natural farming:**

According to National Mission on Natural Farming Management and Knowledge Portal, Government of India, Natural farming encompasses following principles:

- Implementation of diversified cropping system-based agriculture
- Recycling of naturally available nutrients in fields
- Reuse and recycle of on-farm generated biomass
- Use of locally developed and refined practices based on plant, animal and microbial source as raw materials.
- Farmers employ innovative techniques that are always evolving in response to cropping patterns, regional climates, altitude, soil quality, insect and pest intensity and variability etc.

A healthy soil microbiome is crucial for soil, plant, animal, and human health. To achieve this, farmers should maintain diverse crops, practice minimal soil disturbance like no-till or shallow tillage, and integrate animals into farming. Integrated farming systems and the use of bio-stimulants, often produced through the fermentation of animal dung and uncontaminated soil, are vital. Returning organic residues like crop leftovers and compost to the soil is essential. Pest management should prioritize agronomic practices and botanical pesticides over synthetic chemicals, as this harm the regenerative process. Synthetic fertilizers and biocides should be avoided.

**Components of natural farming**:

1. **Jivamrita/jeevamrutha:** It is a beneficial organic biostimulant made by fermenting well-rotted cow dung, cow urine, jaggery, and water for around 48 hours. This nutrient-rich liquid fertilizer enhances soil fertility, stimulates microbial activity, and aids plant nutrient absorption, contributing to sustainable agriculture by reducing the need for synthetic inputs
2. **Bijamrita/Beejamrutha:** Bijamrita is a natural seed treatment solution for crops, prepared by soaking seeds in a mixture of cow dung, water, lime and cow urine. After soaking, the seeds are dried and then sown. This traditional practice is believed to enhance seed germination, protect against diseases, and promote healthy plant growth in an organic and sustainable manner.
3. **Acchadana – Mulching:** Subhash Palekar suggests the following types of mulching:

a) **Soil Mulch:** Preserves topsoil during farming and refrains from tilling it. Furthermore, it helps the soil retain water and aerate. Palekar has recommended against deep ploughing.

b) **Straw Mulch:** The dried biomass waste from earlier crops is hinted to by the straw particles. As Palekar indicates, this could consist of the decomposing remains of any living thing, including plants, animals, etc.

c) **Live Mulch (symbiotic intercrops and mixed crops):** To provide the necessary elements to the soil and crops, Palekar suggests that it is crucial to construct various cropping patterns of monocotyledons and dicotyledons cultivated in the same area.

4. **Whapasa – Moisture:** Palekar disputes the widespread nation that plant roots require a lot of water. He challenges the over-reliance on irrigation in green revolution farming in this way. He firmly believes that water vapour is necessary for the roots. He refers to this as Whapasa, the state in which air and water molecules are present in the soil. He stresses using irrigation just at midday and promotes cutting back on its use.
5. **Plant protection measures:** Natural farming emphasizes the use of traditional, organic, and plant-based solutions for pest and disease management. Different "astras" or botanical preparations are utilized for plant protection:

a) **Neemastra:** It is used to eradicate insects or larvae that consume plant foliage and drink plant sap, as well as to prevent or treat diseases. Additionally, this aids in preventing the spread of dangerous insects. Neemastra is a bioinsecticide and pest deterrent for natural farming that is incredibly simple to manufacture.

b) **Agniastra:** Neem leaf pulp, tobacco powder, green chilli powder, garlic paste, and turmeric powder are combined to create a natural insecticide. All sucking pests and caterpillars, such as Leaf Roller, Stem Borer, Fruit Borer, and Pod Borer, are controlled with it.

c) **Brahmastra:** This all-natural insecticide is made from neem, karanj, custard apple, and daphnia leaves, which contain certain alkaloids that deter pests. All sucking pests and concealed caterpillars found in fruit pods are managed by it.

d) **Dashaparni ark:** It serves as an alternative to Agniastra, Bramhastra, and Neemastra. Depending on what's available, it's made with tobacco powder, ginger paste, turmeric powder, Asafoetida, chilli pulp, garlic paste, and any ten leaves. We can utilise the leaves of several plants, such as neem, pogoamia pinnata, Annona sqamosa, Castor, Datura, Rui, Hibiscus, mango, lantana camara and guava. Depending on the extent of the infestation, it is used to control various kinds of pests.

e) **Fungicide:** It is made with cow milk and curd which is found to be very successful in controlling and managing fungal infection.

**Crop residue generation:**

It is estimated that India generates around 500 Mt of crop residue on-farm and off-farm annually (GOI, 2016) [2]. The highest crop residue estimate was recorded for Uttar Pradesh (109.2 t). Other high crop residue producing states are Maharashtra (52.7 t) and Madhya Pradesh (45.0 t) respectively. Cereals, fibers, oilseeds, pulses and sugarcane contributed the majority of crop residue with production estimates of 352 Mt, 66 Mt, 29Mt, 13 Mt and 12 Mt, respectively. Among cereal crops, rice, wheat, maize and millets together contributed 70% of crop residue followed by fiber crops (13%).

**Management of Crop residue:**

- **Livestock feeds and bedding materials:** Crop residues left on the soil surface are eaten by roaming cattle or allowed for grazing by cattle by farmer itself. Small farmers in rural areas depend on crop residues to feed livestock.

- **For household purpose:** Crop residues could be removed from the field and transported to houses to serve for multi-purpose uses in the household as thatching material and fuel.
- **Mushroom production:** Use of residues in mushroom production represents a valuable conversion of inedible crop residues into valuable food, which despite their high moisture content has two to three times as much protein as common vegetables and an amino acid composition similar to that of milk or meat. Wheat and rice straws are excellent substrates for the cultivation of Agaricus bisporus (white button mushroom), Oyster mushroom and Volvariella volvacea (straw mushroom).

**Paddy straw mushroom**

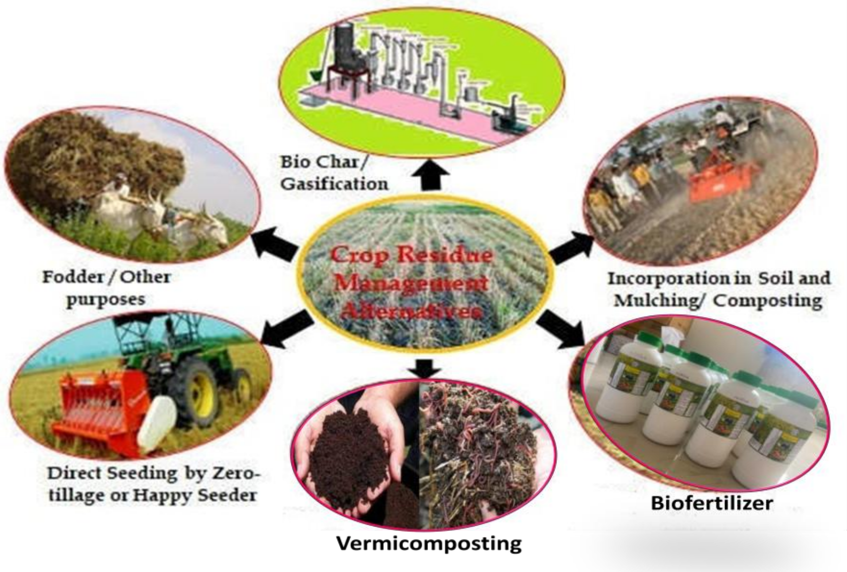
**Oyster mushroom**

- **Mulching:** Residue retention on the surface of soil seems to be a better option for conservation of soil and avoiding water losses by evaporation. It also reduces the weed seed germination and helps in building of soil microbial populations results in increasing soil organic carbon- a direct indicator of soil health. Zero-till wheat has been adopted in the rice wheat system in the northwest IGP with positive impacts on wheat yield, profitability and resource use efficiency. New advance generation seed drill is evolved for this purpose. The Happy seeder works well for direct drilling in standing as well as loose residues provided the residues are spread uniformly. Mulcher machine is used for mulching of straws of crops such as rice, maize, sunflower and tobacco residues easily. This machine shred the weeds and stock of row crops in orchards.

- **Plant Nutrients:** Crop residues are good sources of plant nutrients, are the primary source of organic matter (as C constitutes about 40% of the total dry biomass) added to the soil, and are important components for the stability of agricultural ecosystems. About 40% of the N, 30-35% of the P, 80-85% of the K, and 40-50% of the S absorbed by rice remain in the vegetative parts at maturity (Dobermann and Fairhurst 2000) [1]. Nutrient concentration in crop residues depends on the soil conditions, crop management, variety, season etc. The amount of NPK contained in rice and wheat residues produced (197 Mt) is about 4.1x 106 Mt in India. Crop residues are considered as an important source of several micronutrients. For example, about 50 to 80% of Zn, Cu and Mn taken up by rice and wheat crops can be recycled through residue incorporation (Prasad and Sinha, 1995) [6]. Therefore, returning of crop residues can help improve soil availability of micronutrients. In addition, crop residues may be effective on some soil chemical conditions such as pH.
- **Composting:** Crop wastes are placed in dung pits after being used as animal bedding to prepare compost. Each kilogram of straw that a cow sheds absorbs roughly two to three kilograms of urine, enriching it with nitrogen. The residues of rice crop from one hectare land, on composting give about 3 tons of manure as rich in nutrients as farmyard manure (FYM).
- **Bio-fuel production:** Biofuel is an important strategy to reduce dependence on fossil fuel. Conversion of lignocellulosic biomass into alcohol is of immense importance, as ethanol can either be blended with gasoline as a fuel extender and octane enhancing agent or used as a neat fuel in internal combustion engines. Theoretical estimates of ethanol production from different feedstock (corn grain, rice straw, wheat straw, bagasse and saw dust) vary from 382 to 471 $l\ t^{-1}$ of dry matter. The technology of ethanol production from crop residues is, however, evolving in India.

**Bio-pellet**

- **Biochar production:** Biochar is a fine-grained charcoal having high carbon material produced through slow pyrolysis (heating in the absence of oxygen) of biomass. It can potentially play a major role in the long-term storage of carbon in soil. Biochar converted from plant biomass contains a unique recalcitrant form of carbon that is resistant to microbial degradation, therefore can be used as a carbon sequester, when applied to soil. Lemann and Joseph (2009) [5] reported that biochar produced through slow pyrolysis of plant biomass contains a unique recalcitrant form of carbon that is resistant to microbial degradation, could be used as a carbon sequester, when applied to soil.




**Crop residue management alternatives**

**Crop residue recycling:**

Recycling of crop residues is an essential component in achieving sustainability in crop production systems. Crop residues can be returned to the soil for nutrient recycling, and to improve soil physical, chemical and biological properties (Kumar and Goh, 2000) [3]. • The most cost-effective and environmentally friendly way to preserve soil and water while maintaining crop production is to return crop residue to the soil. Crop residue retention on the soil surface, substantially reduces run-off and soil erosion and can decrease soil evaporation and land preparation costs (Lal, 1989) [4]. Crop residues return carbon (C) to the soil which improves soil structures, improves the ability of the soil to hold nutrients and water holding capacity. Residues provide potassium (K) as well as other nutrient elements that may not be available in inorganic fertilizers. Use of green manuring and returning crop residue plays a key role in growth, performance and yield attributing characters of crop.

**Advantages of crop residue recycling:**

- Improve soil quality
- Recycling of crop residue improve soil productivity and crop production by maintaining SOM levels.
- Increased OM near the soil surface and enhanced nutrient cycling and retention.

- By enhancing microbial activity and biomass close to the soil surface, it serves as a reservoir for nutrients required for crop production.
- In addition to nutrient distribution, changes also occur in the chemical and physical properties of the soil
- Improved soil C sequestration which minimizing agriculture's impact on the environment.
- Convert surplus farm waste into useful product to meet the nutrient requirement of crops
- Recycling of different organic manures besides ensuring hygienic disposal of the organic wastes through Vermicomposting
- Control soil fertility by organic matter and modulate nutrient across diverse soils
- Developing Vermicompost production unit will serve the purpose for utilization of organic manure which sustain fertility and productivity of soil
- Adverse impacts of residues removal for competing uses.
- An increase in the risk of soil erosion and runoff due to a loss in aggregation and a rise in the soil's vulnerability to crusting and compaction.
- The loss of water and nutrients from the ecosystems also decreases crop growth and yields and reduces agronomic productivity effective utilization of this vast resource is a major challenge.
- Improper use of crop residues (e.g. removal, burning or plowing deplete soil fertility, and pollute environment through burning and eutrophication of surface and contamination of groundwater.
- Principal source of $CO_2$ emissions, along with those of greenhouse gases (GHGs) like $CH_4$ and $N_2O$.

**Crop residue and its role in soil organic carbon management**

- Crop residue constitute an important resource
- Significant impact on soil quality and resilience, agronomic productivity, and GHG emissions from soil to atmosphere
- Principal source of Carbon which constitutes about 40 % of the total biomass on dry weight basis
- Increase in rate of application of biomass C increases the SOC pool
- Magnitude of increase in SOC pool depends on other management input used in conjunction with crop residues mulch
- Fertilization of wheat residues with N increased humification of biomass and enhanced the C sequestration rate on the soil

**Conclusion:**

The various crop residues and recycled wastes not only increase crop yield but also benefitted farmers through different crop wastes viz, straw, stubble, leaves, etc., sustain environment, human health and overall national economy. So, crop production, through natural farming, reduces health risk to farm workers and consumers by minimizing their exposure to toxic and persistent chemicals on farm and in food and at the same time boosts up their health status as well.

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# GENOMIC SELECTION: A NEW APPROACH OF MARKER – ASSISTED SELECTION

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**Abstract**

Genomic Selection (GS) is a plant breeding method used to predict the genetic value of untested lines based on genome-wide marker data. While GS has been extensively studied with both simulated and real data, the best strategy for its implementation in breeding programs remains unclear. The accuracy of GS is influenced by factors such as training population size, individual relationships, marker density, and the incorporation of pedigree data. Typically, GS focuses on predicting additive genetic value, often overlooking non-additive genetics. This article provides insights into genomic prediction models for GS and highlights key considerations regarding the data utilized in these models.

**Introduction**

Quantitative traits that are crucial for agriculture are typically regulated by numerous small-effect genes, making them challenging to utilize effectively in breeding programs. These small-effect genes are difficult to map, and even when mapping is successful, multiple quantitative trait loci (QTL) often exist, complicating their simultaneous use in breeding efforts. As a result, other approaches in marker-assisted selection (MAS), which involves using mapped genes in breeding, has seen limited success in enhancing these traits (Heffner *et al*., 2009). GS is a promising approach that seeks to address these limitations for quantitative traits. Rather than pinpointing specific QTL, GS aims to assess the genetic potential of individuals across the entire genome. Initially developed for livestock breeding, GS utilizes markers that span the whole genome to predict the breeding values of individuals based on simulated data. Early applications of GS in dairy cattle breeding demonstrated significant improvements in selection accuracy (Bernardo and Yu, 2007). It's worth noting that prior to the formal establishment of GS, plant breeders had already begun exploring similar concepts. For instance, Bernardo created a multi-marker MAS approach with random marker effects, which operated within the MAS framework by focusing on markers adjacent to identified QTL. In contrast, the breakthrough of Meuwissen *et al.,*(2001) GS was its ability to bypass the identification of QTL altogether. In GS, the total genetic variance is captured by estimating the effect of each marker within the entire marker set, regardless of significance thresholds, under the assumption that markers are in linkage disequilibrium (LD) with the QTLs. Marker effects are determined using individuals that possess both genotypic and phenotypic data. These estimated marker effects are then combined with an individual's marker information to calculate the genomic estimated breeding value (GEBV). The model's predictive ability is assessed through a cross-validation system, which utilizes both a training population and a testing population to refine the model. Marker effects are derived from genotypes and phenotypes within the training population, and these effects are subsequently used to estimate GEBVs for the testing population. Finally, the model's predictive accuracy is evaluated by correlating the GEBVs with the phenotypes of the testing population.

**Requirement of GS**

**Size of training population**

Numerous studies have demonstrated that prediction accuracies are affected by the size of the training population. It is crucial for breeders to identify the appropriate number of lines to genotype and phenotype in order to create an effective training data set, as establishing this initial training data often requires a significant investment. Nielsen *et al.,*(2016) found that the accuracy of GS decreased when the training data set was reduced. Additionally, they noted that accuracy measurements were less stable during cross-validation rounds, with greater variations in accuracy observed for smaller training population.

**Relatedness between Training and Testing population**

The accuracy of GS models is influenced by the genetic relatedness between lines in the training and testing populations. Isidro *et al.,*(2015) reported the highest prediction accuracies when the training population encompassed the entire population and exhibited a strong correlation with the testing population.

**Cross validation (CV)**

To initially assess genomic prediction accuracies, most studies employ CV within the training data, as established by Meuwissen *et al.,*(2001). The two primary CV strategies are leave-one-out (LOO) and *k*-fold CV. In LOO, one line is excluded and predicted using the remaining lines, a method utilized by Nielsen *et al.,*(2016). In *k*-fold CV, the population is divided into *k* random groups, with one group left out for prediction based on the others. Stratified k-fold CV allows grouping by factors such as families, breeding cycles, or environments, again leaving one group out for prediction.

**Marker density**

Meuwissen (2009) observed that prediction accuracies improve with increased marker density, suggesting that at least one marker should be in LD with each QTL to capture all genetic variation in a population. Cericola *et al.,*(2017) found that using 1,000 randomly selected markers was sufficient to achieve maximum prediction accuracy in wheat breeding lines. Additionally, high marker density is particularly important for predicting more distant relatives (Norman *et al*., 2018).

**GEBV**

Best Linear Unbiased Prediction (BLUP) for estimating breeding values using a pedigree-based relationship matrix has been established in animal breeding for selection based on phenotypes and pedigree. This pedigree-based BLUP is foundational for the widely used genomic BLUP (GBLUP) method for estimating GEBV. Meuwissen *et al.,*(2001) initially compared four statistical methods for genomic selection: least-squares estimation, BLUP, and two Bayesian methods, BayesA and BayesB. More comprehensive comparisons by De Los Campos *et al.,*(2013) indicated that when predicting close relatives with traits influenced by many small-effect genes, the differences among methods are minimal, with (G)BLUP and ridge regression being effective and robust. However, for traits with larger QTL or when predicting distant relatives, Bayesian and machine learning methods can enhance prediction accuracy, particularly BayesB and BayesC(pi). In plant breeding, kernel methods are also favored for predicting non-additive effects and managing complex multi-environment, multi-trait models.

**Pedigree**

In plant breeding, selection based solely on pedigree has not received the same attention as the shift to genomic GS using markers. Consequently, a thorough understanding of the benefits of phenotypic versus pedigree selection in plants is lacking. Cericola *et al.,*(2017) found that using markers slightly improved prediction accuracy compared to pedigree alone. Additionally, combining pedigree and genomic information for GS has shown gains in prediction accuracy compared to using markers alone.

**Additive and Non-Additive Genetic Effects**

In species where genotypes can be replicated through cloning or selfing of inbred individuals, it is important to differentiate between additive genetic value and total genetic value (TGV), the latter encompassing all non-additive effects. Most GS efforts focus on predicting additive genetic value, which is crucial for assessing an individual's potential as a parent. However, a variety's market value is determined by its TGV. Therefore, breeding programs should aim to accurately estimate both additive genetic values and TGV. If genomic information can provide precise TGV estimates, it could enhance the prediction of early-stage breeding materials with strong market potential. Models that estimate epistatic interactions, such as the Hadamard product of the genomic relationship matrix or kernel methods like Reproducing Kernel Hilbert Space (RKHS), show promise in this regard. Research by Perez-Rodriguez *et al.,* (2012) indicated that non-linear models like RKHS achieve higher prediction accuracy, likely due to their ability to capture gene interactions effectively.

**Conclusion**

GS using whole-genome markers is a valuable tool for plant breeders, but its optimal implementation remains debated. High selection accuracy is achievable within breeding cycles, while across-cycle predictions may be less reliable due to low relatedness between training and testing populations. Further research is needed on predicting distantly related individuals, especially when using untested parents, as this can lead to lower accuracies. Combining GS with pedigree information can enhance prediction accuracy and help estimate breeding values for non-genotyped lines.

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# INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) IN FISHERIES AND AQUACULTURE

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**Abstract**

Fisheries and aquaculture are vital for global food security. However, traditional practices and limited access to information constrain the sector's potential. ICTs, including mobile phones, GPS, and the internet, offer a transformative solution. By providing real-time market data, weather forecasts, and scientific knowledge, ICTs empower fishers to make informed decisions, improving efficiency and reducing waste. Furthermore, ICTs facilitate communication and collaboration among fishers, enabling knowledge sharing and collective action. Government initiatives are crucial for maximizing the benefits of ICTs. This includes investing in digital literacy programs, expanding infrastructure, and creating supportive policies. By embracing technology and promoting digital inclusion, the fisheries sector can achieve sustainable growth, enhance livelihoods, and contribute significantly to food security and economic prosperity.

**Keywords:** ICTs in fisheries, Digital transformation, Food security

## Introduction

Fisheries and aquaculture are crucial sectors for providing affordable protein to a growing global population. Beyond their nutritional value, they significantly contribute to national economies through income generation, foreign trade, food security, and employment opportunities. Information and Communication Technologies (ICTs) have the power to revolutionize the fisheries sector. By utilizing ICT tools such as mobile phones, GPS, satellite communication, and the internet, fishers and aquaculture farmers can access real-time market information, weather updates, and scientific knowledge. This empowers them to make informed decisions, improve efficiency, and reduce post-harvest losses. Moreover, ICTs facilitate communication and collaboration among stakeholders, enabling knowledge sharing and collective action. The adoption of ICTs can lead to increased production, reduced costs, and enhanced product quality. It can also facilitate the development of value chains, connecting producers to consumers and markets. By creating economic opportunities and improving livelihoods, ICTs can contribute to the sustainable development of coastal and rural communities.

Information and Communication Technologies (ICTs) encompass technologies that facilitate electronic communication and information processing and transmission. This broad definition includes a wide range of technologies such as radio, television, video, DVDs, telephones (both fixed-line and mobile), satellite systems, computer hardware and software, and associated services like video conferencing, email, and blogs. In essence, ICT is a comprehensive term encompassing all advanced technologies for information manipulation and communication. The advent of ICTs has brought in a knowledge explosion across all facets of human development, significantly accelerating growth and development in various sectors. Fisheries, one of the fastest-growing sub-sectors of agriculture, are considered a sunrise sector with immense potential to address global food and nutritional security challenges.

Modern technological advancements have significantly revitalized the fisheries sector, transforming it into a dynamic industry. The integration of Information and Communication Technologies (ICTs) has profoundly impacted the lives and livelihoods of fisher folk. The adoption of ICT tools like GPS navigation, satellite communication, and wireless connectivity has accelerated the expansion and development of the fisheries sector. By enhancing the livelihood activities of fisher folk and mitigating vulnerabilities, ICTs have paved the way for social equality and integration, empowering fisher folk to participate fully in societal development.

Despite significant advancements, rural communities often struggle to access crucial information in understandable formats, hindering timely decision-making. New information and communication technologies (ICTs) offer promising solutions to address the challenges faced by rural populations and boost agricultural production through the dissemination of scientific information. However, a significant barrier remains i.e. the lack of basic communication infrastructure in these rural areas.

**Revolutionizing fisheries and aquaculture with ICTs**

New technologies are revolutionizing the fishing industry, from finding fish to selling it. Special tools like sonar help locate fish underwater. General tools like GPS help boats navigate, phones connect fishermen for trade and emergencies, radios keep communities informed, and websites provide information and networking opportunities. Introduction of mobile phones in India has brought about a tremendous change in fisheries sector. One result was a dramatic improvement in the efficiency and profitability of the fishing industry. As mobile phone service spread, it allowed fishermen to land their catches where there were wholesalers ready to purchase them. This reduced waste from between 5-8 per cent of total catch to close to zero and increased average profitability by around 8 per cent. At the same time, consumer prices fell by 4 per cent.

Different communication technologies have been used by the fishermen, entrepreneurs, aqua culturist, extension workers, etc. of all these, radio has been found to be most widely used by farmers. Information on various innovations of fisheries technologies are being disseminated among the farmers. The internet is emerging as a tool with potential to contribute to rural development. Internet enables rural communities to receive information and assistance from other development organisations: offer opportunities for two-way and horizontal communication and for opening up communication channels for rural communities and development organisations. It can facilitate dialogue among communities and with government planners, development agencies, researchers, and technical experts: encourage community participation in decision-making; coordinating local, regional and national development efforts for increased effectiveness; and help agricultural researchers, technicians, farmers and others in sharing information. Internet can also give a vast global information resource. The Internet has proven valuable for the development of Fisheries in developing countries like India.

**Initiatives in Fisheries Sector:**

**1. ATIC (Agricultural Technology Information Center)**

ATICs can play a crucial role in the fisheries and aquaculture sectors by bridging the knowledge gap, facilitating technology transfer, supporting sustainable practices, and improving market access. By disseminating research findings on fish health, nutrition, breeding techniques, and sustainable aquaculture practices, ATICs can equip fishers, aquaculture farmers, and extension workers with the latest information. They can also promote best practices, such as efficient and environmentally friendly fishing methods and low-impact aquaculture techniques, to minimize negative impacts on ecosystems. Furthermore, ATICs can promote collaborations between scientists and industry professionals to develop and implement innovative technologies, such as aquaculture recirculation systems and biofloc technology. By providing technical assistance and training programs, ATICs can help farmers adopt these technologies and improve their productivity and efficiency.

To promote sustainability, ATICs can encourage responsible fishing practices, such as selective fishing gear and marine conservation efforts, and advocate for eco-friendly aquaculture, like organic aquaculture and integrated multi-trophic aquaculture (IMTA). They can also provide guidance on mitigating the environmental impacts of aquaculture, such as water pollution and habitat destruction.

In addition, ATICs can play a vital role in connecting producers to markets, both domestic and international. By providing market information on trends, prices, and consumer preferences, ATICs can help farmers and fishers make informed decisions about production and marketing. They can also encourage the development of value-added fish products, such as smoked fish, fish oil, and fishmeal, to increase the value of their catches and improve their livelihoods. By serving as a central hub for information exchange, technology transfer, and capacity building, ATICs can contribute significantly to the sustainable development of the fisheries and aquaculture sectors, ensuring food security, economic growth, and environmental protection.

**2. Kisan Call Centre**

The Department of Agriculture & Cooperation (DAC) under the Ministry of Agriculture, Government of India, has established Kisan Call Centres across the country to provide extension services to the farming community, including fishers and aquaculture farmers. These call centers are equipped with telecommunication infrastructure, computer support, and a team of Subject Matter Specialists (SMS) who are experts in various fields of agriculture, including fisheries and aquaculture.

Farmers can call these toll-free numbers to seek advice on a wide range of topics, such as fish health management, feed formulation, water quality management, pond preparation, seed selection, harvesting techniques, and market information. The SMS at the call centers can provide timely and accurate information to farmers in their local languages, helping them to address their specific problems and improve their productivity. The Kisan Call Centres have been particularly beneficial for small-scale fishers and aquaculture farmers who may not have access to extension services or technical expertise. In addition to providing technical assistance, Kisan Call Centres can also play a role in promoting sustainable fisheries and aquaculture practices. They can disseminate information on responsible fishing techniques, such as selective fishing gear and marine conservation efforts, and encourage the adoption of eco-friendly aquaculture practices, such as organic aquaculture and integrated multi-trophic aquaculture (IMTA).

### 3. Aqua Service Centres

Aqua service centers, akin to agri-clinics, are emerging as a valuable resource for aquaculture farmers. These centers, staffed by skilled youth, offer a range of essential services such as soil and water testing, feed analysis, seed quality assessment, disease diagnosis, and market intelligence. By providing these services, these centers help farmers improve their aquaculture practices, optimize resource utilization, and enhance the overall productivity and sustainability of their operations. Additionally, they often sell essential inputs like feed, fertilizers, and medications, providing a one-stop solution for farmers' needs. This innovative approach empowers farmers, boosts the aquaculture industry, and contributes to the sustainable production of aquatic food resources.

### 4. One Stop Aqua Shop

One of the key recommendations of the DFID-funded project "Investigating improved policy on aquaculture service provision to poor people" was the establishment of One-Stop Aqua Shops (OAS). These shops are designed to serve as a single point of access for farmers, providing them with essential information and inputs for aquaculture. OAS aim to bridge the information gap by offering insights into appropriate aquaculture technologies, government schemes, rural banking options, and microfinance opportunities. Additionally, they act as a retail outlet, selling vital inputs like fish seed, fertilizers, and chemicals. By disseminating information through brochures from state departments and research institutes, OAS empower farmers to make informed decisions and adopt sustainable aquaculture practices.

### 5. Aqua Choupal

Aqua Choupals, a pioneering web-based initiative by ITC Ltd., is revolutionizing the aquaculture sector in Andhra Pradesh. By providing farmers with essential information, products, and services, Aqua Choupals empower farmers to enhance productivity, improve farm-gate prices, and reduce transaction costs. Through a user-friendly web portal accessible in Telugu, farmers can access the latest local and global information on weather patterns, scientific farming practices, and market trends, all from the comfort of their villages. Furthermore, Aqua Choupals facilitate the supply of high-quality farm inputs and the purchase of shrimps directly from farmers' doorsteps. This integrated approach streamlines the supply chain, ensuring timely access to resources and efficient market linkages.

Inspired by the success of Aqua Choupals, the M.S. Swaminathan Research Foundation initiated the 'Info Villages' project to address food security concerns. This project offers local language content and wireless internet access, providing vital information to rural communities. Since its inception in 1998, the project has expanded to numerous villages in Pondicherry, empowering fishing communities with crucial data on fish density in the ocean. These innovative initiatives demonstrate the significant impact of technology and information dissemination in the fisheries and aquaculture sector. By bridging the digital divide and providing farmers with the tools they need to succeed, these projects contribute to sustainable aquaculture practices, improved livelihoods, and enhanced food security.

### 6. Rural Knowledge Centre

The Rural Knowledge Centre (RKC) is a nationwide initiative launched in July 2004 by the Central government in collaboration with state governments, NASSCOM, UNDP, and various NGOs. The primary objective of RKC is to establish multipurpose resource centers in villages across the country.

These centers are managed by local self-help groups and are designed to promote knowledge-based livelihoods and create income opportunities for rural communities, farmers, and marginalized populations. By providing access to information, technology, and training, RKC aims to empower rural communities and contribute to sustainable rural development.

**7. Cyber Extension**

The internet has emerged as a powerful tool with the potential to revolutionize rural development, including the fisheries and aquaculture sector. By connecting rural communities to a vast network of information and resources, the internet empowers farmers and fishers to improve their livelihoods and practices.

**Key benefits of cyber extension**

1. Access to Information: The internet provides farmers and fishers with access to a wealth of information, including the latest research findings, best practices, market trends, and weather forecasts. This knowledge empowers them to make informed decisions and adopt innovative techniques.
2. Market Access: The internet facilitates market linkages, enabling farmers and fishers to connect with buyers directly, bypassing intermediaries and securing better prices for their products. E-commerce platforms and online marketplaces provide opportunities to reach a wider market.
3. Knowledge Sharing: Online forums, social media platforms, and digital communities enable farmers and fishers to share experiences, knowledge, and lessons learned with peers. This fosters collaboration, innovation, and the development of sustainable practices.
4. Remote Learning and Training: Online courses, webinars, and video tutorials offer flexible and accessible learning opportunities for farmers and fishers. This helps them acquire new skills and improve their technical expertise.
5. Early Warning Systems: The internet can be used to disseminate early warnings about natural disasters, disease outbreaks, and other threats to aquaculture and fisheries. This enables timely action to mitigate risks and protect livelihoods.
6. Policy Advocacy: Online platforms can be used to advocate for policies that support the interests of fishers and farmers, such as fair trade, sustainable fishing practices, and environmental conservation.

**Conclusion**

Fisheries is one of the fastest developing industries and there is an increasing need in proper information, technologies, and farming techniques dissemination, such as the Code of Good Management Conduct in Fisheries. Lack of communication facilities in communities inhibits the social political and economic empowerment of the majority of the population. Extension today has to assume multiple roles of providing information about technologies, prices and market, policies; organising farmers for exchange of information, facilitating learning from experiences; provide problem solving consultancy in order to serve the farming community. Fish farmers now need quality information about technological options in farming to produce and participate better in markets. They need to know not only market prices but also trends about market prices to plan cultivation. To make information transfer more effective, greater use will need to be made of modern information technology and communication among researchers, extensionists and farmers.

**Conflict of interest :** Authors declare no conflicts of interest.

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# PACKAGING SOLUTIONS FOR INTERMEDIATE MOISTURE FOODS (IMF)

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## Introduction

Intermediate Moisture Foods (IMF) contain moderate levels of moisture (15-50%), which is less than what is normally present in natural F&V, but more than what is left in dehydrated products. Lowering of $a_w$ below 0.80 increases osmotic pressure by sugars, salt, organic acids which controls the growth of bacteria and yeasts, however, moulds often grow on semi-dried fruits ($a_w$ 0.60 – 0.65). Low $a_w$ slows the rate of respiration, enzymatic action and overall deterioration rate that increases shelf-life. IMF do not require refrigeration and is less expensive to store and transport.

### What is Water Activity ($a_w$)?

It is a measure of unbound, free water in a system available to support biological and chemical reactions. $a_w$ for fruits & Vegetables is in the range of 0.991 - 0.999 and $a_w$ for dried vegetables is about 0.2. When a food is in moisture equilibrium with its environment, then the $a_w$ of the food will be quantitatively equal to the equilibrium relative humidity (ERH) divided by 100.

### Food Classification Based on Free Moisture Content

1. High moisture foods (50 to 99%)
   - Fruits, Vegetables, Juices, Raw Meat, Fish
2. Intermediate moisture foods (15-50%) (IMF)
   - Jam, Jelly, Marmalade, Honey, Fruit bars/Fruit Leathers (e.g., Aam Papad), Bread, Hard Cheeses
3. Low moisture foods (0-15%)
   - Dehydrated Vegetables, Grains, Milk Powder, Dry Soup Mixes

**Food Classification based on pH:** The acid in the foods can either be present naturally (as in fruits), produced during fermentation (as in fermented foods), or added during processing (as in salad dressings). The pH range of growth of molds is 1.5 to 9.0; for yeasts, 2.0 to 8.5; for Gram-positive bacteria, 4.0 to 8.5; and for Gram-negative bacteria, 4.5 to 9.0. The toxin producing and most challenging bacteria *Clostridium botulinum* can grow in pH ≥ 4.6 but can NOT grow in pH < 4.6. Therefore, low-acid or high-pH (pH > 4.6) products are given 12D treatment to destroy Cl. botulinum Type A and B spores (the most resistant spores of a pathogen) and for high-acid or low-pH (pH > 4.6) products, such as tomato products and fruit products a much lower heat treatment is used. The spore formers that can germinate and grow in low pH products (e.g., *Bacillus coagulans*) and the aciduric non-spore-forming bacteria (e.g., *Lactobacillus* and *Leuconostoc spp.*), yeasts, and molds that can grow at low pH are relatively heat sensitive. These products are generally heated about $100^0$C for a desirable period of time.

On the basis of pH, food has been divided into 4 categories as below:

1. Low acid: pH > 5.0
   - Beans, Corn, Peas, Potatoes, Cauliflower, Meat, Poultry, Seafood, Milk
2. Medium acid: 4.5 < pH < 5.0
   - Soups, Sauces, Asparagus, Beets, Pumpkin, Spinach, Green Beans, Turnip, Cabbage
3. Acid: 3.7 < pH < 4.5
   - Tomato, pear, fig, pineapple, apricot, beer
4. High acid: pH < 3.7
   - Sauerkraut, Pickles, Berries, Aonla, Citrus, Rhubarb, Plums, Apples, Strawberries, Peaches, Jam, Jellies, Honey, Wine, Vinegar

There are various packaging options available in the market to package IMF and processed foods obtained from the value addition of fruits and vegetables, meat and dairy. Their selection depends upon the product and its storage requirements. They may be of different types:

(i) rigid metal containers such as cans and drums,
(ii) flexible metals as in aluminum and tin foils,
(iii) glass as in jars and bottles,
(iv) rigid and semi-rigid plastics as squeeze bottles,
(v) flexible plastics as in pouches and wrappers,
(vi) rigid card-board, paper and wood as in boxes,
(vii) flexible papers as in boxes, bags and laminates and
(viii) multiplier laminates which may combine paper, plastic and foil.

**Packaging Interventions for IMF: Key Requirements**

1. **Moisture Barrier:** Prevents moisture migration to maintain the desired water activity level, ensuring texture and microbial stability.
2. **Oxygen Barrier:** Protects against oxidation of fats, oils, and other sensitive components, preserving flavor, color, and nutritional value.
3. **Seal Integrity:** Ensures the package remains airtight to prevent external contamination.
4. **Mechanical Strength:** Protects against physical damage during transport and handling.
5. **Aesthetic Appeal:** Offers branding and consumer information while attracting potential buyers.

**Common Packaging Materials for IMFs**

**Flexible Pouches:** Materials used are Laminated films made of polyethylene (PE), polyethylene terephthalate (PET), and aluminum foil. Advantages are excellent barrier properties, lightweight, resealable options, and customizable printing for branding.
**Applications:** Dried fruits, soft cookies, and snack bars.

**Rigid Plastic Containers:** Materials used are Polypropylene (PP), high-density polyethylene (HDPE), and polyethylene terephthalate (PET). Its advantages are being durable, reusable, good moisture and oxygen barriers when combined with appropriate seals.
**Applications:** Cheese spreads, intermediate moisture meats.

**Glass Jars:** It is made up of glass with metal or plastic lids featuring hermetic seals. It is non-reactive, excellent oxygen and moisture barriers, premium feel for consumers.
**Applications:** Specialty IMFs like fruit preserves or artisanal cheeses.

**Metal Cans:** Metal cans are made up of Tin-plated steel or aluminium and may have different types of coatings (Table 1). They have excellent barrier properties for long shelf life, durable, recyclable.
**Applications:** Processed cheese spreads or moisture-controlled baked goods.

**Composite Materials:** Composite Materials are made up of cardboard lined with aluminum foil or plastic. They are lightweight, cost-effective, good barrier properties when laminated.
**Applications:** Bakery products and other semi-moist snacks.

**Active Packaging:** It incorporates oxygen scavengers, moisture absorbers, or antimicrobial agents into the packaging. It extends shelf life by actively controlling the internal atmosphere.
**Applications:** Sensitive IMFs with high-fat content or prone to microbial growth.

**Advanced Solutions**

- **Modified Atmosphere Packaging (MAP):** It replaces air in the package with a controlled gas mixture (e.g., nitrogen or carbon dioxide) to reduce oxygen levels and prolong freshness.
- **Edible Coatings:** In edible coating an additional protective layer applied to the food surface to reduce moisture loss and oxidation.

**Considerations for IMF Packaging**

Intermediate Moisture Foods (IMFs) require packaging that addresses several technical challenges, primarily related to maintaining water activity and protecting against environmental factors like oxygen, light, and mechanical stress. These are:

**1. Moisture Barrier Properties**

- Key Metrics: Water Vapor Transmission Rate (WVTR), measured in g/m²/day.
- Materials:
  - Low-Density Polyethylene (LDPE): Common due to its flexibility and low cost but requires lamination for enhanced barrier properties.
  - Polypropylene (PP): Superior to LDPE in moisture barrier performance.
  - Metallized Films (e.g., Aluminum Foil): Offer near-zero WVTR, ensuring minimal moisture migration.
- Example: Packaging dried apricots in PET/Aluminum/PE laminate reduces moisture loss compared to single-layer plastics.

**2. Oxygen Barrier Properties**

- Key Metrics: Oxygen Transmission Rate (OTR), measured in cc/m²/day.
- Materials:
  - Ethylene Vinyl Alcohol (EVOH): Excellent oxygen barrier but sensitive to moisture, often used in multi-layer films with PE or PP for protection.
  - Aluminum Foil: Provides complete oxygen barrier, essential for products prone to oxidative rancidity, such as intermediate moisture cheeses.
- Applications:
  - Soft baked goods: Use PET/EVOH/PE structures to prevent oxidation while maintaining product softness.

**3. Seal Integrity and Heat Sealing**

- Seal Strength Testing: ASTM F88 standard measures the force required to separate the sealed area of a package.
- Sealing Methods:

- Thermal Sealing: Suitable for multi-layer films with internal heat-sealable layers (e.g., PE or PP).
- Induction Sealing: Used for rigid containers like glass jars with metal caps.
- Considerations: Improper sealing can lead to moisture ingress, oxygen entry, or contamination, compromising the shelf life of the product.

**4. Active Packaging Technologies**

- Oxygen Scavengers:
  - Incorporates iron-based sachets or integrated films that react with oxygen to create an anaerobic environment.
  - Application: Extends the shelf life of fatty IMFs like semi-dried sausages.
- Moisture Regulators:
  - Silica gel or molecular sieve sachets absorb excess moisture in humid environments.
  - Film-integrated absorbers regulate internal humidity within a narrow range.
- Antimicrobial Films:
  - Embedded with silver ions or organic compounds like nisin to reduce microbial growth on product surfaces.

**5. Modified Atmosphere Packaging (MAP)**

- Gas Composition:
- Nitrogen ($N_2$): Displaces oxygen to prevent oxidation and mold growth.
- Carbon Dioxide ($CO_2$): Inhibits bacterial and fungal growth, especially in dairy-based IMFs.
- Gas Flush Ratios: For baked goods, a ratio of 70% $N_2$ and 30% $CO_2$ is common.
- Equipment: High-speed MAP machines with integrated gas analyzers ensure precise control of gas composition.

**6. Mechanical and Physical Protection**

- Drop and Compression Testing: Packaging is tested for durability under simulated shipping and handling conditions using ASTM D4169 standards.
- Shock-Absorbing Layers:
- Use of air-filled or foam inserts within rigid containers for products like soft cheeses.

**7. Light Barrier Properties**

- Sensitive Products: IMFs containing fats and pigments (e.g., carotenoids in cheese) degrade upon UV or visible light exposure.
- Materials:
- Metallized films or opaque laminates provide effective light shielding.
- Pigmented plastics (e.g., black or white PP) block harmful wavelengths.

**8. Sustainability and Consumer Appeal**

- Recyclable Options:
- Mono-material structures (e.g., all-PE or all-PP) are easier to recycle compared to multi-layer laminates.
- Compostable Alternatives:
- Polylactic Acid (PLA)-based films offer moisture barrier properties but are less effective for long-term oxygen protection.

- Design Innovations:
- Resealable zippers for flexible pouches enhance usability and reduce waste.

**Cost-Effectiveness Analysis**

- Material Optimization: Combining thin-gauge aluminum with PET and PE ensures barrier properties without excessive costs.
- Automation: Investment in high-speed packaging lines with precise sealing and gas flushing reduces labor costs and ensures consistency.

***Selection of the packaging material should be done on the basis of 4 major considerations:***

1. Targeted Shelf Life: Select materials and designs based on the desired product longevity.
2. Storage Conditions: Factor in temperature and humidity variations in the supply chain.
3. Consumer Convenience: Ensure ease of opening, resealing options, and ergonomic designs.
4. Sustainability: Use recyclable, biodegradable, or compostable materials where possible to align with consumer preferences for eco-friendly packaging.

**TABLE 1. Types of Can Coatings**

| Coating | Typical uses | Type |
|---|---|---|
| Fruit enamel | Dark coloured berries, cherries and other fruits requiring protection from metallic salts | Oleoresinous |
| C-enamel | Corn, peas and other sulphur-bearing products | Oleoresinous with suspended zinc oxide |
| Citrus enamel | Citrus products and concentrates | Modified oleoresinous |
| Beverage can enamel | Vegetable juices; red fruit juices; highly corrosive fruits; non-carbonated beverages | Two-coated with resinous base coat and vinyl top coat |

**Conclusion**

By tailoring packaging solutions to the specific needs of Intermediate Moisture Foods, manufacturers can ensure product quality, safety, and consumer satisfaction while addressing sustainability and market demands. By integrating the technical aspects, packaging solutions for IMFs can preserve product quality, meet regulatory requirements, and appeal to environmentally conscious consumers. Continuous innovation in materials and technology will further enhance the functionality and sustainability of IMF packaging.

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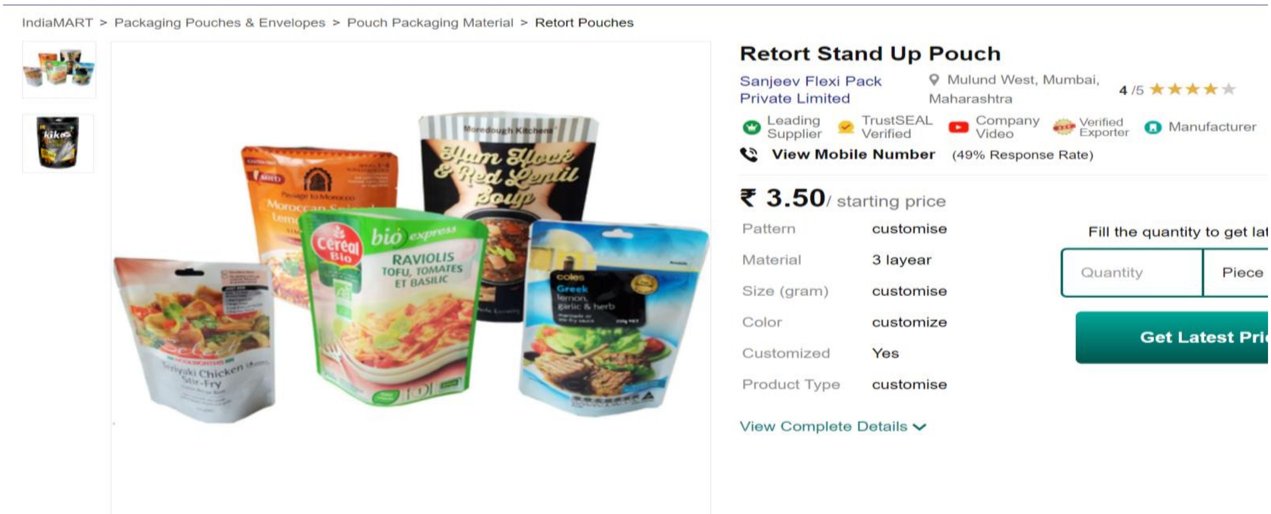
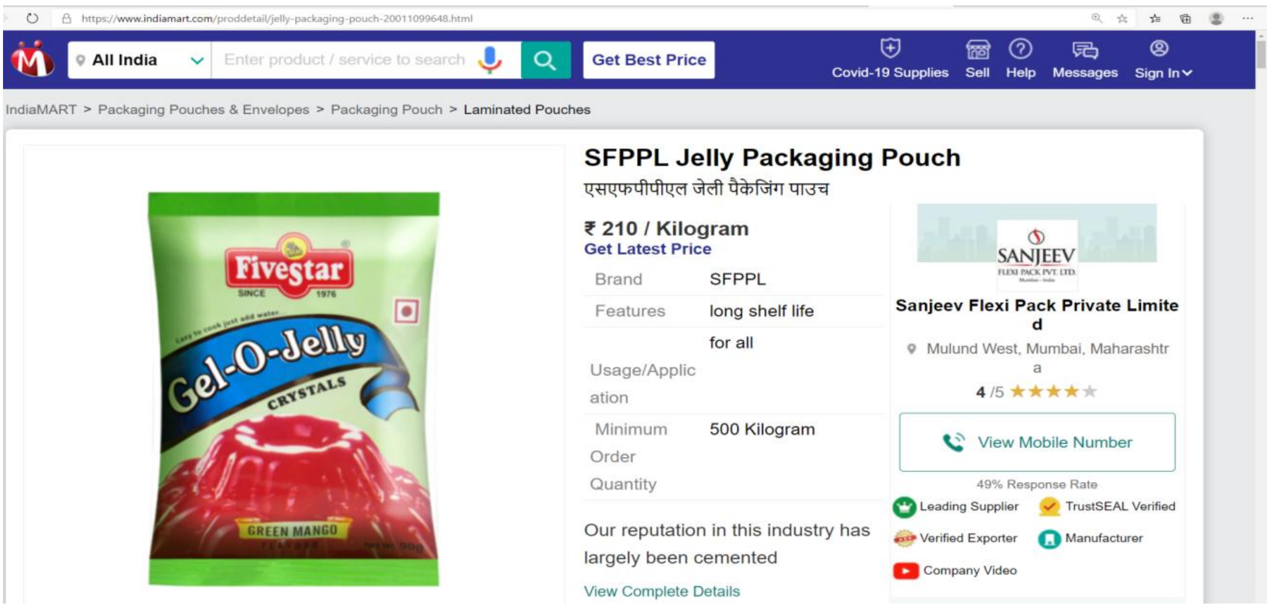
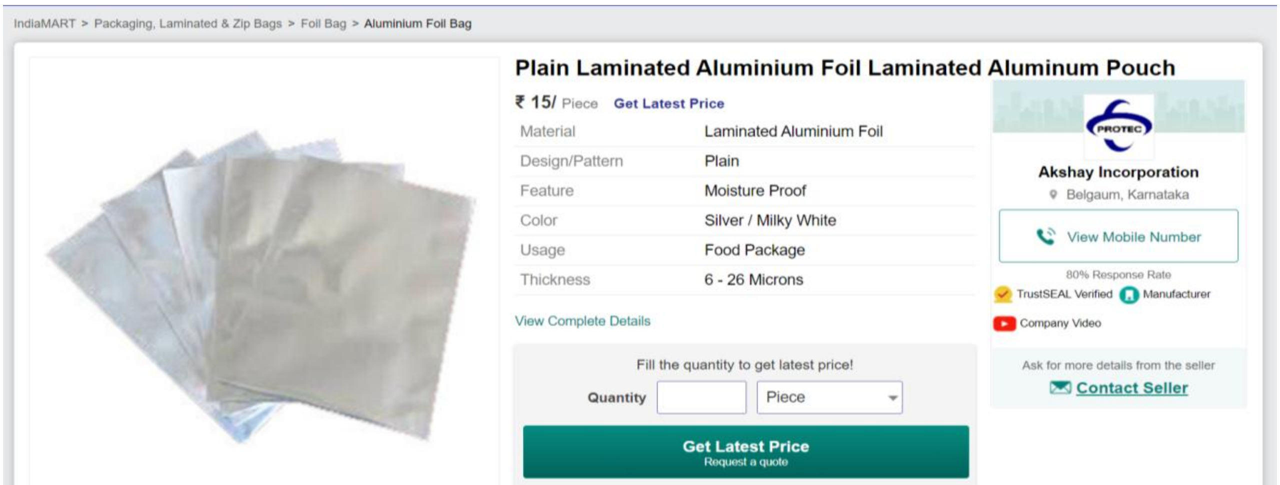
**Some Packaging materials available for sale online (*prices and details are shown here just for educational purpose and idea for the reader*):**



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# ROLE OF PLANT SECONDARY METABOLITES IN PLANT DEFENSE

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## Abstract

Secondary metabolites are organic chemicals found in plants that are not directly engaged in essential metabolic functions like energy production, growth, or reproduction. These substances are essential to plant immune systems because they allow plants to defend against a variety of biotic and abiotic threats. In addition to shielding plants from environmental challenges like dehydration and UV rays, secondary metabolites can serve as chemical inhibitors against herbivores, diseases and rival plants. They consist of a wide range of compounds with distinct defensive roles, including flavonoids, phenolics, terpenoids and alkaloids. This article covers the several defense functions of secondary metabolites found in plants, emphasizing their ecological importance, protective processes and possible uses in both agriculture and medicine.

**Keywords:** Phytochemicals, Secondary metabolites, Plant defense mechanisms, Herbivore resistance, etc.

## Introduction

Plants face numerous environmental challenges throughout their life cycles, including herbivory, pathogen attacks, competition for resources and abiotic stress such as drought, extreme temperatures and UV radiation. Since plants cannot move like animals can, they must protect themselves from these dangers using a range of chemical, physical and biological defenses. The creation of secondary metabolites-complex, frequently bioactive substances that are vital for plant life and fitness but not necessary for fundamental metabolic processes-is one of the most significant of these systems (Herrmann *et al*., 2021). Secondary metabolites are broadly classified into four major categories: alkaloids, terpenoids, phenolic compounds and sulfur containing compounds. Each of these groups contains diverse chemical structures that perform specific roles in defense, including deterring herbivores, suppressing pathogens and enhancing tolerance to environmental stresses (War *et al*. 2020). Apart from their defensive roles, these metabolites play an important role in interactions between plants, microbes and insects by signaling and communicating with other species. Secondary metabolites play a very

dynamic and context-dependent function in plant defense, depending on the particular difficulties the plant encounters as well as its evolutionary background (Wink, 2018). Over the course of evolution, plants have developed a vast array of secondary metabolites, each with specialized functions that contribute to their overall survival and reproduction. This article aims to review the roles of plant secondary metabolites in defense, focusing on their ecological significance and potential applications (Schafer and Wink, 2009).

**Classification of Secondary Plant Metabolites**

The primary types of secondary metabolites that plants produce are,

A. Terpenes
B. Phenolics
C. Nitrogen
D. Sulphur containing compounds.

**A. Terpenes**

- Acetyl Co-A or glycolytic intermediates are the main source of these metabolites. These are further divided into five subclasses.

i. **Monoterpenes $C_{10}$:** Several portions of the chrysanthemum plant include monoterpene esters that have insecticidal properties against a variety of insect groups, such as lepidoptera, hymenoptera and coleoptera. These substances, which include limonene, myrcene, α-pinene and β-pinene, are mostly found in the plant's trunk, twigs and resin ducts. They have been demonstrated to be poisonous to bark beetles in conifers, which are a subclass of gymnosperms that are a group of seed plants bearing spikes.

ii. **Sesquiterpenes $C_{15}$:** Sesquiterpene compounds, such as costunolide, are significant anti-herbivore agents, characterized by five-membered lactone rings. These compounds exhibit strong feeding repellency against mammals and a wide range of herbivorous insects.

iii. **Diterpenes $C_{20}$:** Diterpenes found in trees belonging to the leguminous group and pine are secreted as resin compounds through the pore canals of the trunk when the tree is injured by insects. These resin substances help block insect feeding and act as a deterrent to further damage.

iv. **Triterpenes $C_{30}$:** The milkweed produces bitter-tasting glucosides, such as sterols, to defend against cattle and insects. The complex limonoid molecule known as azadirachtin, which is extracted from the neem plant *Azadirachta indica*, has a number of harmful effects and deters some insects.

v. **Polyterpenes:** Rubber is another polyterpene located in lengthy vessels known as laticifers, which contain 1,500 to 15,000 isopentenyl units. These laticifers serve as a protective mechanism, helping to heal wounds caused by herbivores, as reported by Eisner and Meinwald (1995).

**Terpenoids as attractants to predators or parasitoids**

- At certain doses, (Z)-3-hexenyl acetate and linalool effectively attract *Chrysopa phyllochroma*, although (3E)-4, 8-dimethyl-1,3,7-nonatriene and linalool can increase the parasitism of *C. phyllochroma* females.

However, the parasitoid *Cotesia glomerata* gets attracted to the same terpenoid found in the volatile organic compounds (VOCs) released by cabbage plants. It lays its eggs in the caterpillar *Pieris brassicae*, which consumes particular herbivores.

**Terpenoids as attractants to beneficiaries**

Terpenes serve as signals to pollinators about the various stages of flowers. The volatiles released by responsive fig trees contain three monoterpenes: limonene, β-pinene and linalool. Wasps react to these compounds' quality (substitution with other isomers) as well as quantity (changes in concentration).

**B. Phenolic compounds**

**Coumarin:** Coumarin that are wide spread in the vascular bundles and acts against herbivores.

**Furano Coumarins (members of Umbelliferae):** UV-A light activates these chemicals, making them hazardous. Because resistant maize germplasm contains secondary metabolites that are produced in the plants by larval feeding, it affects the maize stalk borer, *Chilo partellus*. On *Sesamia inferens* larvae, a diet incorporation experiment containing phenolic substances, such as ferulic and p-coumaric acids, showed an antibiosis effect.

**Lignin:** Lignin is derived through the oxidation of alcohols such as coniferyl, sinapyl and coumaryl by the plant enzyme peroxidase. The proportions of the monomeric units in lignin vary across species, plant organs and even within different layers of a single cell wall. Lignin compounds, known for their high chemical durability, contribute to the physical toughness of plants, making it difficult for herbivores and animals to digest.

**Flavonoids:** New pesticides are being developed using identified flavonoid compounds as a promising alternative to synthetic pesticides, driven by the growing demand for plant-based products. Flavonoids inhibit enzyme activity, effectively arresting the larval growth of insect species in their early instars. Compounds such as naringin, rutin and quercetin are used as insecticidal agents in managing the aphid, *Eriosoma lanigerum* Hausmann.

**Tannins:** Tannins are toxic compounds that hinder the survivorship, growth and development of herbivorous insects and animals. They effectively prevent phytophagous insects from feeding. Tannin-rich plants with low protein levels show greater deterrence against herbivores than plants with higher nutritional content but the same level of tannins. These tannins induce a severe irritation in the mouths of insects due to the adhesion of salivary proteins. Therefore, plants having a high tannin content are typically avoided by mammals including deer, cattle and apes (Wouters *et al*., 2016).

**C. Sulphur compound**

**GSH (Glutathione Synthetase):** GSH (glutathione) is produced by plants in response to sulfur deficiency. This mobile and highly soluble form of sulfur is easily absorbed by the plant to address the sulfur shortage, helping to regulate plant growth. GSH also functions as a cellular antioxidant in stressful situations and helps plants become more resistant to microbial attacks.

**GSL (Glucosinolates) (**Brassicaceae family)**:** GSL (glucosinolates) are nitrogen- and sulfur-containing plant glucosides produced by plants to enhance resistance against insect pests. When a plant is attacked by insects, GSL breaks down into isothiocyanates, which activate the plant's antioxidant defense system. This helps protect the plant from insect damage (Hopkins *et al*., 2009).

**Defensins:** As the name indicates defensins are antifungal and anti-bacterial. These are also pathogen-inducible and are expressed in higher amounts when subjected to pathogen attack.

**Phytoalexins**: Numerous secondary plant metabolites with potent antibacterial qualities, known as phytoalexins, build up near the infection site. Common phytoalexin chemicals produced by plants include orchinol in orchid tubers, pistin in *Pisum sativum* pods, glyceollins in soybeans (*Glycine max*) and phaseolin in *Phaseolus vulgaris* pulses. The hypersensitive reaction (HR), also referred to as apoptosis, is a plant defense mechanism that can occasionally result in the death of plant cells due to the formation of phytoalexins.

**Thionins:** Thionins are essential for protecting and improving plants' defensive systems against insects, microbes and animals. Infected wheat spikes containing higher levels of thionins showed increased resistance to *Fusarium culmorum*.

**Lectins:** Defensive proteins called lectins attach themselves to carbs or proteins that contain carbohydrates. Lectins interfere with the absorption of nutrients by attaching themselves to the intestinal epithelial cells when consumed by herbivores.

**D. Nitrogen containing compound**

**Alkaloids:** Alkaloids are abundantly present in the vascular tissues of plants, with higher concentrations found in dicots compared to monocots and gymnosperms. Among these, pyrrolizidine alkaloids (PAs) are important for protecting plants from insect herbivory and microbiological diseases.

**Cyanogenic Glucosides (**Graminae, Rosaceae and Leguminosae**):** When a plant is damaged, it readily breaks down to release volatile toxic gases such as HCN (hydrogen cyanide) and $H_2S$ (hydrogen sulfide). The production of HCN occurs when the cell contents of several plant tissues mingle during herbivore feeding. This gas's release serves as an anti-feedant and a deterrent to insects. Such substances include dhurrin in Sorghum bicolor and amygdalin in the seeds of almonds, apricots, cherries and peaches.

**Non-protein Amino Acids**: These compounds act as barriers against insect pests. For example, azetidine and canavanine are analogues of proline and arginine, respectively and they interfere with the intake of amino acids by insects. Because canavanine binds to the enzyme that typically binds arginine, canavanine is incorporated into the arginine transfer RNA (tRNA) molecule rather than arginine. This causes the production of a non-functional protein in its place, which interferes with insects' arginine metabolism (Isman and Paluch, 2011).

**Adaptation of insects to secondary metabolites in plants**

In insects, detoxifying enzymes are present in the midgut lumen and cytoplasmic cells. Normally found in trace amounts, these enzymes become more abundant when the insect consumes harmful compounds. The elevated concentration of detoxifying enzymes helps convert the toxic metabolites into less harmful forms.

**Detoxification by cytochrome P450:** P450s are the primarily used by insects against plant allelochemicals.

*E.g.* In case of *S. frugiperda*, the toxic metabolites, 2 – phenylethyl isothiocyanate detoxified in insect midgut by P450.

In cotton, one of the important SM gossypol is detoxified by P450 monooxygenase. In the bark beetles the SM are detoxified by P450s.

**Glutathione S-transferases:** Detoxification by GSTs (Glutathione S-Transferases) occurs in the insect haemolymph, fat body and midgut. When glutathione is conjugated with electrophilic hazardous compounds, insect GSTs catalyze the creation of water-soluble glutathione S-conjugates, which the insect can readily break down and get rid of. Because *Myzus persicae* has been shown to have high levels of GST, these aphids can consume brassicaceous plants that contain glucosinolates and isothiocyanates, which they can detoxify.

**Conclusion**

Secondary metabolites are crucial to plant defense, equipping plants with a diverse range of strategies to protect themselves from herbivores, pathogens and environmental stresses. These compounds serve a variety of functions, from acting as chemical deterrents to directly inhibiting microbial growth and are key to the ecological success and survival of plants. By producing these bioactive molecules, plants not only enhance their own resilience but also shape interactions within their ecosystems. Beyond their ecological roles, secondary metabolites offer significant potential for practical applications in agriculture, medicine and industry. Harnessing the defensive properties of these compounds could lead to innovative solutions for sustainable pest control, disease management and improving crop resilience to environmental stress, ultimately supporting food security and environmental sustainability.

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# RESTORATION OF WETLANDS AND MANGROVES

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**Abstract**

Wetlands and mangroves are the most crucial factors in the environment as they act as natural filters, trapping pollutants, sediments, and nutrients, provide habitat for a wide range of species, including many endangered and migratory birds, fish, amphibians and plants. These also act as natural sponges, slowing down the flow of water and mitigating the impact of heavy rainfall and storm surges, also stabilize shorelines and riverbanks through their vegetation, reducing erosion caused by water flow and wave action which helps to maintain the integrity of landscapes and prevents loss of valuable land. Due to numerous activities (mainly human activities) various areas of wetland and mangroves are degraded and destroyed which is responsible for ecosystem disturbances. Therefore the ecological restoration is needed which is the process of renewing the degraded or destroyed environment. Restoration is vital for maintaining ecosystem health, enhancing biodiversity, mitigating climate change, improving water quality and providing economic and recreational benefits.

**Keywords**: Mangrove, Restoration, Wetland.

**Introduction**

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. It involves the active intervention to reestablish the structure, function, diversity, and dynamics of an ecosystem. Wetland and mangrove restoration also included in the ecological restoration. The main goals of restoration are conserve the biodiversity, habitat, restoration of ecosystem services that benefit environment such as nutrient cycling, water filtration and energy flow (Erwin, 2009). Also it increases the ecosystem's ability to withstand and recover from disturbances, and ensure long term sustainability and self maintenance of restored ecosystems, provides socio-economic benefits, such as improved livelihoods and ecosystem services (Romanach *et al*., 2018).

**Wetland Restoration:**

Wetland restoration is the process of renewing, returning degraded or destroyed wetlands to their natural state to restore their ecological functions and services. A successful wetland restoration requires a comprehensive, multi-disciplinary approach that integrates ecological, hydrological and social considerations to achieve sustainable outcomes (Taillardat *et al*., 2020).

**Environmental Benefits:**

1. Biodiversity conservation: wetlands are the important factor for ecosystems, these provides habitat for a wide range of endangered and migratory birds, fish, amphibians and plants. Restoration of wetlands helps to protect and enhance biodiversity.
2. Water quality improvement: wetlands act as natural filters, trapping pollutants, sediments, and nutrients. This improves water quality by reducing contaminants that is entering from another rivers, lakes, and groundwater.

3. Flood control: wetlands absorb and store excess rainwater, reducing the risk of floods. They act as natural sponges, slowing down the flow of water and mitigating the impact of heavy rainfall and storm surges.
4. Carbon sequestration: these are significant carbon sinks, storing carbon in their vegetation and soil. Restoration of wetlands help in mitigate climate change by capturing and storing atmospheric carbon dioxide.
5. Erosion control: wetlands stabilize shorelines and riverbanks through their vegetation, reducing erosion caused by waterflow and wave action. Restoration helps to maintain the integrity of landscapes and prevents loss of valuable land.
6. Recreation and tourism: Healthy wetlands provide opportunities for recreational activities such as bird watching, fishing and boating, contributing to local economies through tourism.

**Techniques for wetland restoration:**

Various methods are used for wetland restoration as following,

- Hydrology Restoration: It includes re-establishing natural water levels and water diversion and rehydration process. Re-establishing natural water levels technique includes eradication of artificial drainage systems, such as ditches, tiles, or pumps and installing water control structures like weirs, dams, or levees to retain water at desired levels. Water diversion and rehydration includes redirecting streams, rivers, or other water resources to flow into the wetland to restore its natural hydrological regime.
- Vegetation Management: It includes introduction of native species and eradicate the invasive species. Introduction of native species includes planting native wetland plants such as grasses, sedges, trees etc., which are suitable for specific conditions of the wetlands. Controlling invasive species encompasses the implementation of physical, chemical, or biological methods to remove the invasive plants and animals which responsible for threatening native biodiversity (Erwin, 2009).
- Soil and Sediment Management: It includes soil amendments which means addition of organic matter or other amendments to improve soil quality and promote plant growth. Also includes erosion control process, using some techniques such as planting vegetation, installing silt fences, or applying erosion control fabrics to stabilize soil and prevent erosion.
- Reconstructing wetland topography: It includes grading, contouring and creating microhabitats. Grading and contouring involves adjusting the land surfaces to create appropriate elevations and slopes that support wetland hydrology and habitat diversity. Creation of microhabitats includes construction of some features like pools, swales, hummocks and channels to enhance habitat diversity and support a variety of wetland species.
- Water quality improvement: Nutrient management and pollution control in wetlands is a major factor in the restoration of wetlands. It includes reduction of nutrient inputs from surrounding areas through best management practices such as buffer strips, cover crops, and controlled fertilizer application. Implementation of numerous measures to prevent or reduce pollution from agriculture, urban, or industrial sources also crucial to improve water quality.
- Monitoring and Adaptive Management: Regularly measuring key indicators such as water quality, vegetation cover and wildlife populations leads to the success of restoration efforts.

Collection of monitoring data to make informed adjustments to the management practices and restoration techniques to improve outcomes.

- Community and stakeholder involvements: In this process local residents, landowners and stakeholders are involved in the planning, implementation and maintenance of wetland restoration projects. Also includes providing education and outreach to increase awareness and support for wetland conservation and restoration efforts.

**Steps in a Wetland Restoration Project:**

- Site Assessment and Planning: Includes baseline studies to understand the current conditions, historical context, and ecological potential of the site. Setting clear restoration goals and objectives based on scientific data and stakeholder input.
- Design and implementation: Developing a detailed restoration plan that outlines the techniques, timelines and resources needed and implementation of restoration activities, such as re-establishing hydrology, planting native species and constructing habitat features.
- Monitoring and maintenance: Establishing a monitoring program to track the progress of restoration efforts and ensure the goals are being met. Performing regular maintenance activities such as controlling invasive species, repairing structures and replanting vegetation ad needed.
- Evaluation and reporting: Analyzing monitoring data to evaluate the effectiveness of restoration and identification of areas for improvement.

**Mangrove Restoration:**

Mangrove restoration is crucial for a variety of environmental, economic and social reasons. It aims to rehabilitate and re-establish mangrove ecosystems, which are essential for coastal protection, biodiversity and supporting local communities or habitats (Lovelock *et al*., 2020).

**Environmental benefits:**

- Enhanced ecosystem services: Healthy mangrove ecosystem provide a wide range of services such as nutrient cycling, habitat provision, climate regulation which are essential for environment.
- Coastal protection: Mangroves protect shorelines with their complex root systems, reducing coastal erosions caused by waves and currents.
- Protection from Natural Disturbances: Mangroves act as natural barriers, absorbing and dissipating the energy of storm surges and reducing the impact of coastal flooding (Romanach *et al*., 2018).
- Habitat for wildlife: Mangroves provide shelter to a wide range of species, including fish , birds and invertebrates. They serve as a breeding and nursery grounds for many marine organisms.
- Support for Endangered Species: Mangroves support several endangered species by providing their habitats that are essential for their survival.
- Carbon sequestration: Mangroves are highly efficient at sequestering carbon dioxide, storing large amounts of carbon in their biomass and sediments. This helps to mitigate climate change by reducing greenhouse gas concentrations in the atmosphere.
- Pollutant reduction: Mangrove filters and traps sediments, nutrients and pollutants from runoff which leads to improve water quality and protecting downstream coral reefs and seagrass beds.

- Sustainable Harvesting: Mangroves offer numerous resources such as timber, fuelwood and non-timber products that can be sustainably harvested also provide income to the local community.
- Tourism and recreation: Healthy mangrove ecosystems attract tourists for activities like bird watching, fishing and several other recreational opportunities and contribute to the local economies, enhance the quality of local residence life (Romanach *et al*., 2018).

**Techniques for mangrove restoration:**

- ✓ Site selection and assessment:
  Identifying suitable sites with appropriate tidal conditions, salinity and sediment types. Then conducting ecological assessments to understand the hydrology, soil properties, existing vegetation and potential stressors.
- ✓ Hydrology restoration: it includes some processes such as restoration of tidal flows which ensure natural tidal exchange by removing or modifying obstructions like dikes, levees, that disrupts the water and another process is water level management, which is done by constructing channels to improve tidal inundation or using tidal gates to control water flow.
- ✓ Planting and propagation:
  - ❖ Direct planting: Mangrove plant seedlings or propagules directly planted in the restoration site . it involves digging holes and placing propagules at the appropriate depth.
  - ❖ Nursery development: Grow the mangrove seedlings in nurseries to ensure a stable supply of healthy plants for transplantation, which allows better control over the early stages of growth.
  - ❖ Species selection: Native mangrove species of that particular restoration site should be selected (Ellison, 2000).

- Bioengineering Technique: This process includes utilization of natural materials like coconut coir logs, bamboos, stakes or other organic barriers to reduce erosion and stabilize sediments. These structures can also help trap sediment and build up substrate.
- Invasive species control: Various methods are used to eradicate the invasive plants and animals that can compete with or harm mangroves.
- Community engagement and livelihood support: It involves in engaging local residents in restoration process through education, proper training and participatory planning.
- Monitoring and adaptive management: It involves some processes such as track progress through regular assessments of vegetation cover, hydrological conditions, soil quality and wildlife presence. Monitoring data is used to take adaptive measures to improve restoration techniques and management practices.

**Steps in Mangrove Restoration Project:**

- ➢ Initial assessment: site should be selected by conducting site survey and feasibility studies to gather information on environmental conditions, socio-economic factors and potential risks.
- ➢ Restoration plan: Prepare a detailed plan that includes restoration goals, methods, timelines and budget. Consider stakeholder input and integrate traditional knowledge.
- ➢ Site Preparation: Clear any debris, invasive species, or barriers that impede restoration efforts. Modify hydrology if necessary to restore natural water flows.

- Planting activities : Implementation of appropriate planting techniques such as direct planting, transplanting nursery grown seedlings. Protect young plants from herbivory and physical damage.
- Regular monitoring and maintenance: establish a monitoring schedule to assess the health and growth of mangroves, hydrological conditions and overall ecosystem recovery. Necessary maintenance such as replanting, controlling invasive species and repairing erosion control structures (Lovelock *et al*., 2022).
- Evaluation and reporting: By analyzing monitoring data evaluation of the effectiveness of restoration effort is done, through which it is possible to identify the success of the project and areas of improvement.
- Stakeholder reporting: share the results with stake holders , funders , and regulatory bodies to demonstrate progress and build support for ongoing and future restoration efforts.

**Conclusion**

Due to the increased human activities environmental degradation has become more extensive and intensive. Sudden increase in the diversity of restoration challenges is increasing the scope of what is considered to be restoration. Restoration projects increasingly address components of the ecosystem. Restoration is poised to become a truly integrated and collaborative field and essential to maintain ecosystem services.

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# ENRICHING THE ORGANIC MANURES TO IMPROVE THEIR EFFICIENCY

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**Abstract**

Organic manures in general supply major and micronutrients along with improving the soil physical, chemical and biological properties. The issue arises when the manures to meet the crop demands need to apply in bulk quantities which mostly range in tons as these contain very low amounts of nutrients per unit. Therefore, in such cases the enrichment of the manures using various biological inputs and additives improves the nutritional status and reduces the application quantity. Additionally, it improves the performance of the manures and crop productivity. Various methods have been developed for various manures which can be adapted depending on resource availability and producer convenience.

**Introduction**

Utilization of various organic manures has been increasing lately due to the pollution constraint caused by burning of the residues, increased demand for the organic food, ill effects of chemical fertilizers and awareness regarding the protection of environment. Manure can be obtained from various sources such as livestock, green manures, compost prepared from crop residues and other farm wastes, vermicompost, oil cakes, farm residues along with urban waste, biological wastes - animal bones, slaughterhouse refuse.

Generally, manure is an organic product which provides nutrients in low concentrations and thus requires large quantities to meet the plant nutrient demands and will also improve the soil biota. It is tiresome to meet the demand of large quantities of manures because of the source constraint along with its long preparation time. To reduce these impacts, the enrichment of the manures can be done which improve the quality of the manures such as nutrient supply, pest and disease control and microorganism's status while reducing the quantity of such applied manures.

Enrichment of manures can be done by the addition of biofertilizers, bioinoculants and permitted mineral additives to the given quantity of the manure and followed by decomposition of the residues and multiplication of microorganisms for a period. Once the manure is ready it will be applied as basal as such or can be mixed with other components and used in pots or nurseries. In general, the manures which are majorly enriched are farmyard manure, vermicompost and poultry manures. By adding biofertilizers and mineral additives, the nutrient availability in the manures as well as soil fertility status and with the addition of bioinoculants the pest and diseases reduction can be achieved.

The major biofertilizers which are used for the enrichment are nitrogen fixing biofertilizers *i.e.,* Rhizobium, Azotobacter and phosphorous solubilizing bacteria (PSB), mineral additives (rock phosphate) and bioinoculants such as Trichoderma and Bacillus. In case of FYM, chemical preservatives *i.e.,* super phosphate and gypsum can be added to preserve the nutrients. With the addition of bioinoculants such as *Trichoderma, Bacillus subtilis*, *Glyocladium* and *Pseudomonas*, the control of fungal and bacterial diseases can be achieved, while insect pests can be controlled by *Metarhizium anisopliae, Bacillus thuringiensis* and *Beauveria bassiana* and nematodes can be controlled through *Paecilomyces* (Sindhu *et al.,*2020).

**Methods for augmentation of manures:**

There are various processes in which the enrichment can be done based on location and available resources (Fig. 1).

**a. Farmyard Manure (FYM)**

i. In case of FYM which is used in conventional farming, addition of chemical preservatives such as gypsum and superphosphate reduce the losses of nitrogen in animal urine along with the addition of calcium and Sulphur to the manure (TNAU). Once it is decomposed fully, it can be applied as basal @ 10-20 t $ha^{-1}$ depending on the crop requirement.
ii. In case of organic farming, the FYM can be enriched with the addition of PSB, Azotobacter, bio mineralizer, rock phosphate and followed by decomposition for 20 to 45 days by regularly monitoring the moisture levels and can be applied at 750 kg $ha^{-1}$ as basal application.
iii. In the method given by ICAR-AAU, the compost is prepared by layering green crop biomass and brown substrates. After 75-80 days, the biofertilizers such as Nitrogen-fixers, PSB and potassium solubilizing bacteria (KSB), along with addition of rock phosphate with further decomposition up to a month will enrich the compost and can be applied @2 to 10 t $ha^{-1}$ depending on the crop.

**b. Vermicompost**

i. Preparation of vermicompost from cow dung along with paper mixtures and 2% phosphorus *via* rock phosphate can be used under organic farming.
ii. FYM can be mixed with other materials and earthworms and convert it into vermicompost leading to enriched condition. Later the addition of various mentioned products will further enhance it.
iii. The addition of vermicompost results in the interaction between the earthworms and the microorganisms which could result in the production of plant growth regulators that ultimately leads to the production of higher yields. Hence, the enrichment of vermicompost with biofertilizers such as *Azospirillum brasilense* and *Rhizobium leguminosarum* and microbial inoculants, results in improved growth and yield of crop.

**c. Poultry manure**

i. Poultry manure is mixed with chopped paddy straw in the ratio of 1:1.25 and then inoculated with *Pleurotus sajor-caju* @ 2.5 kg/t. The moisture in the heap needs to be maintained for 50 days and turning needs to be done at 15-day interval starting from $21^{st}$ after heap formation (TNAU).
ii. Dry fiber free coir pith/dry coir pith needs to be spread in the poultry unit on the floor where the droppings get collected in the coir pith which can be collected after partial decomposition after three months and later can be further composted and utilized (TNAU).


Fig. 1: Enrichment of manures

**Application of manures**

- The manures need to be applied based on the materials available in the location to reduce the burden on budget as we need to apply large amounts as these are low concentrated in nutrients.
- Applying should be done based on the recommended doses given by experienced personnel or should be added after soil testing for nutrient status to balance the crop needs and to prevent overload or dumping.
- Generally, fully decomposed manures such as in the case of enrichment where there is given enough time to decompose the manures can be applied as basal and then can be incorporated into the field.
- There should be enough moisture in the field for the optimal multiplication of the microorganisms after application.

**Beneficial effects of enriching manures**

- Balanced nutrient supply to plants leads to improved yield.
- The incidence of the diseases and weeds has been reduced by killing of pathogenic organisms and weed seeds.
- The microbial activity in the soil can be improved.
- The activity of soil enzymes, soil electrical conductivity, hydraulic conductivity, infiltration rate, accumulation of humus content and ultimately the soil structure is improved, whereas the water holding capacity is increased through reduction in bulk density (Sindhu *et al.,* 2020).
- The quantity of the manure addition will be less with continuous application of enriched manures.
- Economically beneficial as there is an increase in crop performance along with reduced dose of manure application.
- Depending on the chemical fertilizers can be minimized.
- The quality of the yield has been observed to increase owing to the enhanced utilization of atmospheric nitrogen, increase in the root nodule formation, pod yield, cell division and cell elongation leading to boosting in plant growth and development.

**Conclusion**

Enrichment of manures is a favorable task which can be done with the help of various additives and permitted minerals. They reduce the dose of manure application and prevent the wastage of farm residues. Majorly FYM and vermicompost are used for enriching. Enriched manure not only results in improved crop yields but also enhances the soil health by improving the beneficial microorganism's status in the soil which aids in nutrient availability and minimizes the pest and diseases incidence. Soil sustainability can be achieved by properly selecting suitable organic materials and appropriate composting process.

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# REDISCOVERING MAPPILAI SAMBA: THE NUTRIENT-RICH TRADITIONAL RICE WITH EXCEPTIONAL GROWTH AND YIELD QUALITIES

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## Introduction

Traditional rice varieties are abundant in vitamin D, calcium, thiamine, riboflavin, and glutamic acids, as well as fibre. They are low in fat, sugar, and gluten, and contain oryzanol, a chemical that inhibits fat formation in the body, making them an excellent diet for diabetics and hypertensive individuals. Mappilai Samba, or "Bridegroom's Rice," is a traditional rice type from Tamil Nadu, India. This heirloom grain, noted for its tenacity and unusual flavour, is making a comeback as farmers and consumers alike seek indigenous grains that promote sustainable farming and provide unique health advantages (Priya *et al.*, 2019). Mappilai samba is respected in folklore for boosting strength and endurance and is well-known for its nutritional content and resistance. This type was traditionally made for grooms in rural areas before marriage rituals since it was thought to increase their vitality and energy. Mappilai Samba, once revered for its resilience, is now being acknowledged not just for its cultural history, but also for its amazing growth and yield characteristics.

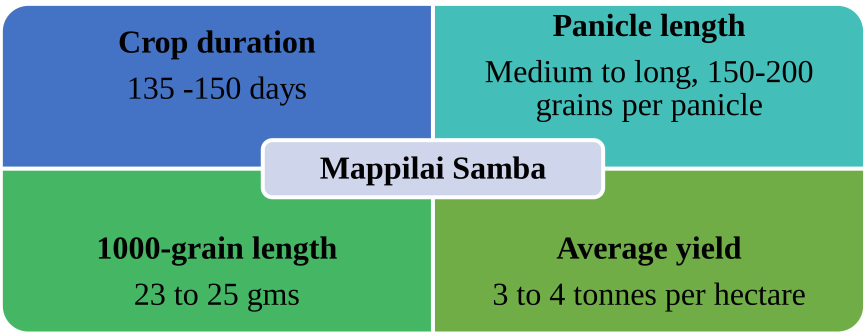


**Figure 1. Growth and yield characteristics of mappilai samba**

## Growth characteristics of mappilai samba

Mappilai Samba is a resilient crop that can withstand drought, it grows well in organic farming environments. It is a native cultivar that grows well in Tamil Nadu's monsoon-fed fields and is tolerant of several soil types. Compared to contemporary high-yielding varieties, this rice variety takes a little longer to mature roughly 135-150 days but it makes up for it with robust pest resistance and flexibility in natural farming methods. There are several growth characteristics let us discuss some important characteristics of Mappilai samba.


(a) (b)

**Figure 2: High-resolution microscopy image of mappilai samba rice (a) with seed coat (b) without seed coat**

**Climate and soil requirements:** Flourishes in tropical regions with moderate to heavy precipitation. Although it can adapt to a range of soil types, it thrives in loamy or clayey soils that are high in organic matter. Although it can withstand waterlogging for a short time, it needs adequate drainage.

**Seed germination and planting:** A moderate rate of germination necessitates appropriate seed treatment before planting. In Tamil Nadu, they are usually sown in the samba (August to December) or Navarai (January to April) seasons. Direct sowing or transplanted following a 25 to 30-day period of seedling care in a nursery.

**Plant morphology:** The crop is prone to lodging in severe winds or heavy rains since it grows tall, usually reaching 140-160 cm. Its endurance under moderate climate stress is attributed to the slim yet sturdy culms. and the deep green leaves appear long and thin.

**Growth duration:** Crop with a medium to long growing season, with a sowing to harvest time of roughly 135 to 150 days.

**Water requirements:** It needs frequent watering, particularly when it's actively tillering and blossoming. Grain yield and quality are improved by regular watering, but it can withstand some drought.

**Nutrient management:** It favours organic farming practices and reacts favourably to natural fertilizers such as vermicompost, green manure, or farmyard manure. Because it requires few chemical inputs, it can be used for environmentally benign and sustainable farming.

**Pest and disease resistance:** The diversity is somewhat impervious to pests such as leaf folders and stem borers. Shows good resistance to common rice diseases, such as bacterial leaf blight and blast, but close observation is necessary.

**Yield potential:** Yield is moderate when compared to high-yielding cultivars, averaging 3-4 tons per hectare under ideal conditions. It is considered more valued for its nutritional value and health advantages than its yield.

**Harvesting:** Harvested manually when grains are fully grown and the plants begin to turn golden yellow. Threshing is frequently followed by sun drying for storage. These are all the general important growth characteristics of Mappilai Samba.

**Yield characteristics of mappilai samba**

Mappilai Samba is a traditional rice type prized for its nutritional and cultural value rather than its high yield. However, understanding its production characteristics is critical for farmers and academics interested in cultivating and preserving this heirloom species.

**Grain yield components**: Mappilai Samba has the following features that contribute to its yield: **Tiller number:** Produces modest tillering (12-18 tillers per plant) as compared to HYVs.Productive tillers (those that bear panicles) have a substantial impact on overall yield. **Panicle characteristics**: The panicle length ranges from medium to lengthy, with 150 to 200 grains per panicle. Grain fullness is high under optimal nutrition and moisture conditions. **Grain weight**: The grains are medium-sized, reddish in colour, and weigh about 23-25 grams per 1000 grains. This weight is slightly lower than that of HYVs, however it is offset by the grain's nutritional content.

**Nutritional and economic yield:** Mappilai Samba is highly valued for its nutritional value, which includes high fibre, iron, and antioxidant levels. Although grain yield is lower, the economic worth of the crop is higher due to its high price in niche markets.

**The role of organic practices in production:** Mappilai Samba flourishes under organic and traditional agricultural methods, which are critical for improving production characteristics: The application of farmyard manure, green manure, and bio fertilizers enhances soil health and grain quality. Organic farming reduces production losses caused by synthetic inputs and promotes sustainable cultivation.

**Yield stability:** Mappilai Samba yields consistently over numerous seasons and under different environmental circumstances. While it does not compete with HYVs in terms of yield, its ability to withstand unfavourable conditions provides continuous output in low-input systems.

**Cultural and traditional significance:** Frequently used in traditional Tamil Nadu foods such as idli, dosa, and porridge. Symbolic in Tamil weddings, where it represents power and vigour, especially for newlyweds.

**Conclusion**

Mappilai samba grains are medium in size and have a reddish tint because of their high anthocyanin content. Even after cooking, it retains its nutty flavour and chewy texture. It is nutritionally rich in iron, fibre, and antioxidants, with a low glycemic index, making it good for diabetics (Veera *et al*., 2022). Mappilai Samba is not a high-yielding rice variety, but it is recognized for its durability, flexibility, and nutritional value. Its moderate production can be increased with good agronomic practices and organic agricultural techniques. It remains an essential component of both sustainable and traditional rice farming systems. Mappilai Samba is a hardy crop with high cultural and nutritional value, appropriate for both organic and traditional farming systems. Its cultivation supports efforts to protect biodiversity and promote sustainable agriculture. Mapillai Samba is more than a rice variety; it represents a cultural legacy and natural resilience. While it may take more time and care to cultivate, its ability to flourish in harsh environments, combined with its nutritional benefits, make it a valued crop for both farmers and consumers who value quality over quantity.

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# MICROBIAL CONSORTIA AND THEIR APPLICATION IN AGRICULTURE

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**Abstract**

Microbial consortia is an ecofriendly and sustainable approach to promote plant growth in contrast to chemical fertilisers whose excessive use has led in depletion of the soil nutrients and soil micro flora and fauna. Microbial consortia perform various activities that promote plant growth by providing essential nutrients to plants and warding off pathogens and also replenishes soil of its lost nutrients. This article aims at providing an insight to its readers about microbial consortia and their application in agriculture.

**Introduction**

Microbial consortia are widely being explored in various sectors of life due to their beneficiary effects, be it pharmaceuticals, food industry, bioremediation processes and in agriculture. But what are these microbial consortia that have so many applications in various sectors. Microbial consortia are group of microorganisms that are compatible with each other and produce a synergistic effect. Microbial consortia are found in the environment naturally and play important role in ecological functioning like cycling of carbon and nitrogen, solubilising of phosphate, decomposition of organic matter and in plant health. Though present naturally, microorganisms interact in different ways in their habitat which includes positive interactions like symbiosis, mutualism and commensalism and negative interaction like parasitism, amensalism and predation. Due to these negative interactions a microorganism may not be able to realise its full potential in its natural environment. Also, consortia are more beneficial than single strain culture as they provide multifunctional roles and have more diverse mode of action together in comparison to single cultures making them more robust to face the environmental challenges.

Microbial consortia are categorised as artificial, synthetic, or semisynthetic. The artificial consortia comprise of microbial strains that have been selected for specific functions and do not coexist together in the environment naturally. Synthetic consortia are made from genetically modified microorganisms and semisynthetic consortia comprises of both natural and genetically modified microorganisms.

**Development of microbial consortia**

For the development of microbial consortia, the primary step involves the screening of microorganisms for the desired function which can be considered as the most crucial step for development of the microbial consortia. Qualitative and quantitative evaluation of the strains for production of the desired trait should be carried out and the strains that show maximum qualitative and quantitative traits should be selected for development of consortia. The next step is to check the compatibility of the strains with each other. The strains should be compatible so that they do not inhibit each other decreasing their desired effects thus is crucial for establishing functionally successful consortium.

**Microbial consortium in agriculture**

**1. Plant growth promotion**

PGPR are a group of bacteria that colonise the rhizosphere and exert positive effect on plant growth and development. They are responsible for fixing nitrogen, releasing phosphate from insoluble forms and making them available to plants, and produce growth regulators like auxins, gibberellins and cytokinin. The interaction is synergistic as plants also secrete carbohydrates, organic acids, and minerals that too promote PGPR nutrition and aid in development of symbiotic associations such as mycorrhizal associations and nitrogen fixing nodulation.

**2. Control of plant diseases**

Microbial consortium aids in controlling plant diseases through various activities that involve production of lytic enzymes, antibiotics, siderophores and volatile compounds that have an inhibitory effect on pathogens. They also compete for nutrients with the pathogens thereby limiting their growth by depleting the nutrients. Microbial consortium also induces induced systemic resistance through ethylene and jasmonic acid.

**3. Bioremediation of agricultural waste**

The increase in generation of agricultural waste calls for solutions that are ecofriendly and can add to the circular economy. The use of microbial consortium to deal with these waste products and turn them into value added products can aid in waste management and add to the economy in a sustainable manner. Along with waste management, microbial consortium can be used in bioremediation of soil contaminated with toxic compounds. Use of consortiums enhances the remediation process that cannot be achieved through use of individual microorganisms.

**Mechanism of action of Microbial consortium**

There are two mechanisms of action of the microbial consortium: Direct and Indirect. The direct mechanisms are involved in plant growth by solubilisation of phosphates, uptake of biologically fixed dinitrogen, chelation of ions like iron, magnesium, boron, calcium and copper, synthesis of plant hormones such as auxins (indoleacetic acid, AIA), gibberellins (gibberellic acid, GA3), cytokinins, ethylene, and abscisic acid (ABA). These are responsible for stimulating stem elongation, root development and increasing aerial biomass production. Indirect mechanisms involve protection of plant by inducing systemic resistance and stimulating the innate resistance of plants.

**Commercialisation of Microbial consortium in India**

A comprehensive legal framework is present in India for the commercialization of microbial consortium as biofertilizers. The Ministry of Agriculture in 2006 categorised biofertilizers under Essential commodities Act of 1966 and brought under Fertilizer Control Act 1985 which specified the production and marketing standards. There were seven quality parameters laid down which included physical form, minimum count of viable cells ($5x10^7$ CFU/g for solid carrier, $1x10^8$ CFU/ml for liquid and 100 viable propagules/g for mycorrhizal fungi), contamination level, pH, particle size (for carrier-based materials), maximum moisture percent by weight of carrier-based products and efficiency character. The list of commercial products in India and rest of the world are listed in Table 1 and Table 2 respectively.

## Conclusion

The use of microbial consortium in agriculture promotes sustainable agriculture by decreasing dependence on chemical fertilisers whose overuse depletes soil of its fertility. In recent times the production and consumption of the microbial consortium as biofertilizers have gained much interest. In India the average consumption of the microbial consortium is about 45,000 t per annum where maximum production is from Agro Industries Corporation, state agriculture departments, National biofertilizers Development Centres, State Agricultural Universities and private sectors. Though the use of microbial consortium has proved to promote the plant growth there is still lack of its usage on wide scale. Developing consortium that have broad spectrum action against pathogens and that can adapt in different environment conditions of pH, moisture, salinity, temperature and humidity would promote its acceptance among farmers.

**Table 1: Commercial Microbial consortia available in India (Sekar et al. 2016)**

| S. No. | PRODUCT | CONSORTIA | COMPANY |
|---|---|---|---|
| 1 | Life® | PGPR consortia | Biomax |
| 2 | Biomix® | PGPR consortia | Biomax |
| 3 | Biozink® | PGPR consortia | Biomax |
| 4 | Biodine® | PGPR consortia | Biomax |
| 5 | Jet 9 | PGPR consortia | Sivashakthi Bio Planttec Ltd. |
| 6 | Calosphere | PGPR consortia | Camson Bio Technologies Ltd. |
| 7 | Calspiral | *Azospirillium* + PGPR | Camson Bio Technologies Ltd. |
| 8 | Symbion-N | *Azospirillium* + *Rhizobium* + *Acetobacter* + *Azotobacter* | T. Stanes & Company Ltd. |
| 9 | Bio Power | *Azospirillium* + *Azotobacter* + PSB + VAM | SKS Bioproducts Pvt Ltd. |
| 10 | Premium EMC | PGPR consortia | International Panacea Ltd. |

**Table 2: Commercial Microbial consortia available in world (Sekar et al. 2016)**

| S. No. | PRODUCT | CONSORTIA | COMPANY | COUNTRY |
|---|---|---|---|---|
| 1 | Nodulator® N/T | *B. subtilis* MBI 600 + *B. japonicum* | BASF Canada, Inc. | Canada |
| 2 | Nodulator® PRO | *B. subtilis* + *B. japonicum* | BASF Canada, Inc. | Canada |
| 3 | BioBoots® | *Delftia acidovorans + Bradyrhizobium sp.* | Brett-Young Seeds | Canada |
| 4 | EVL Coating® | PGPR Consortia | EVL, Inc. | Canada |
| 5 | BioAtivo® | PGPR Consortia | Instituto de Fosfato Biológoco (IFB) Ltda. | Brazil |
| 6 | BioJet® | *Pseudomonas* sp. + *Azospirillium* sp. | Eco Soil Systems, Inc., San Diego, CA | USA |
| 7 | BioYield | *B. subtilis* + *B. amyloliquefaciens* | Gustafson, Inc., Dallas | USA |
| 8 | TagTeam® | Rhizobia + *Penicillium bilaii* | Novozymes | USA |
| 9 | VitaSoil® | PGPR consortia | Symborg | Spain |

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# CONCEPTS OF NATURAL BREEDING IN FINFISH AND ITS APPLICATION FOR INDUCED BREEDING IN AQUACULTURE

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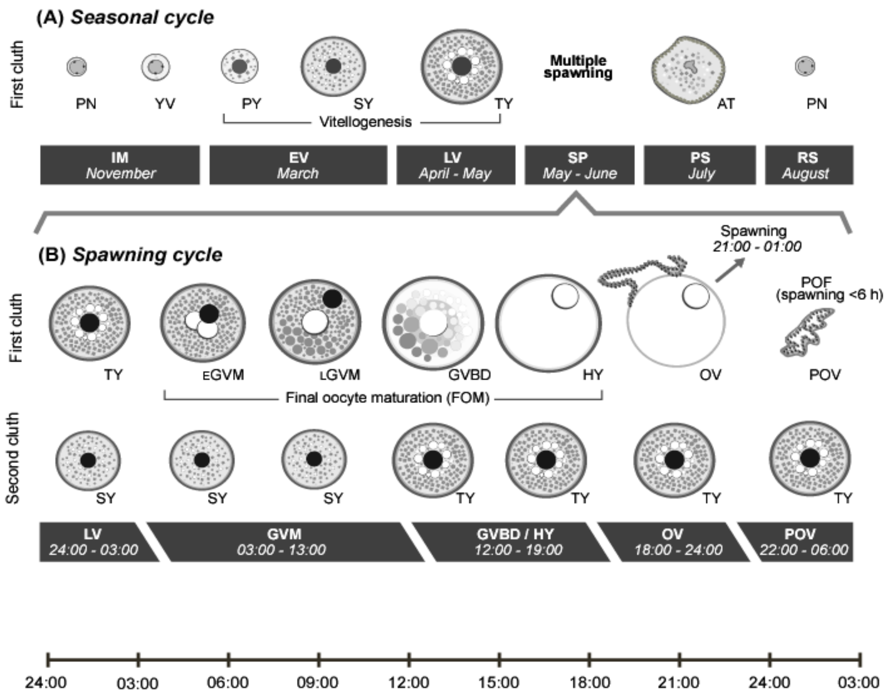
## Introduction

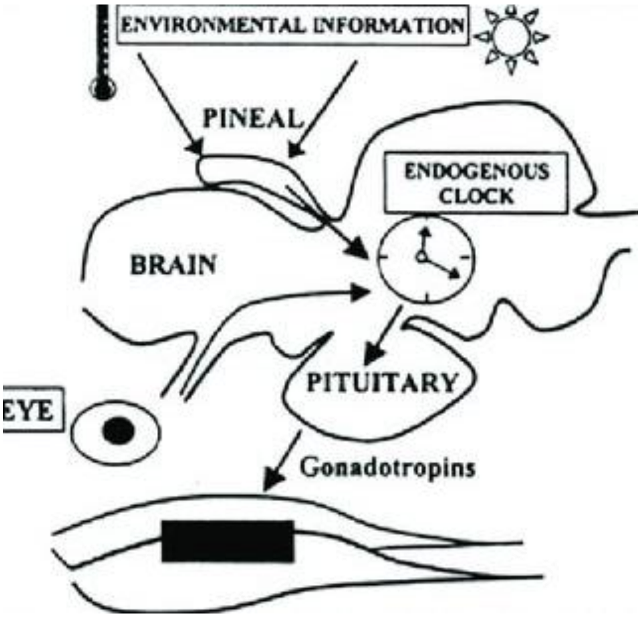
Majority of teleost fishes exhibit seasonal breeding during their life cycle. During a particular and conductive natural time period, many fishes undergo final stages of gonadal maturation and spawning under natural conditions. Also, there are fishes which exhibit year round spawning like tilapia and common carp. These differences are mainly attributed to the hormonal changes taking place at the level of reproductive brain-pituitary-gonad (BPG) axis. Research data indicate that different elements of BPG axis undergo seasonal changes in response to the changing photoperiod and water temperature. In Indian climatic condition, monsoon rains play an important role in the activation of maturation phase in Indian major carps and other cultivable freshwater fishes. Understanding the neuroendocrinological changes in natural fishes undergoing seasonal breeding is important in developing induced breeding methods for aquaculture.




Diagrammatic representation of seasonal and spawning cycle in a marine fish, chub mackerel (Nyuji, Selvaraj et al., 2012). Seasonal cyle: IM, Immature; PN, Perinucleolar oocyte stage; YV, yolk vesicle stage; PY, primary yolk stage; SY, secondary yolk stage; EV, Early vitellogenesis; LV, Late vitellogenesis; SP, Spawning cycle; PS, Post-spawning; RS, resting stage. Spawning cycle: TY, Tertiary yolk; EGVM, early germinal vesicle migration; LGVM, late germinal vesicle migration; GVBD, germinal vesicle migration; HY, hydration; OV, ovulation; POV, post-ovulation. The time indicated below shows the time of the day during which different stages of spawning cycle observed in captivity .

**Seasonal reproduction in finfish**

Seasonal reproduction in fish is controlled by an endogenous rhythm or clock whose periodicity is circannual and the periodicity of this circadian clock is entrained by the seasonal changes in daylength or photoperiod. Circadian clock is reset on a daily basis by environmental changes, primarily an input light, to ensure synchronization of endogenous rhythms with the 24-hour solar day. A major hormonal output of the circadian clock is the rhythmic synthesis and secretion of the pineal organ melatonin, which constitutes an essential component of the circadian timing system in finfish. The pineal organ of fish, situated above the midbrain is differentially sensitive to environmental light intensity, and photoneuroendocrine cells of pineal gland secrete melatonin in response to light. Pineal organ melatonin influences different elements of reproductive axis to regulate pubertal onset and seasonal gonadal growth and maturation events. Also, lunar, semilunar, and tidal cycles of moon-related periodicities also play an important role in daily and multiple spawning during annual reproduction. In recent studies, it is shown that melatonin influences brain kisspeptin to control seasonal reproduction in finfish.



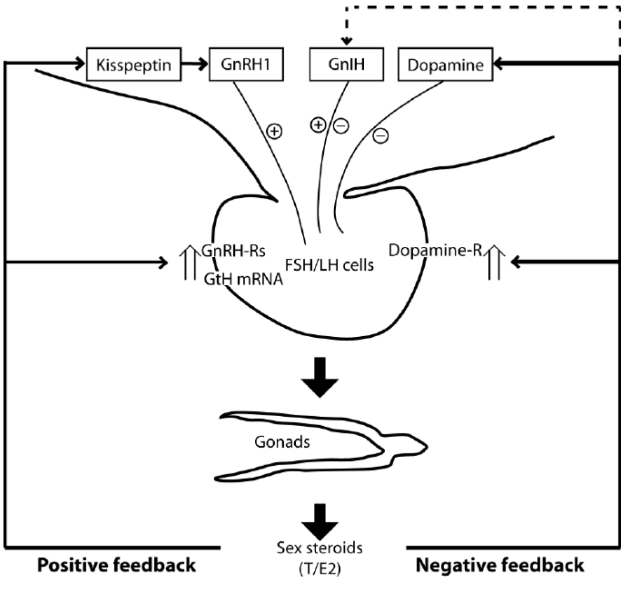

Anatomical location of pineal gland in fish and its involvement in seasonal reproduction of finfish (Source: Francis et al., 2020).

**Role of GnRHs, GtHs and sex steroids in seasonal breeding**

Gonadotropin-releasing hormone (GnRH) is synthesized in the brain and reaches pituitary gland through neuronal axons. Brain GnRH regulates the synthesis and secretion of pituitary gonadotropins. Pituitary gonadotropins consists of follicle stimulating hormone (FSH) and luteinizing hormone (LH). In most of the teleost fish, FSH is involved during the early stages of gametogenesis and LH is involved in the final stages of gametogenesis including spawning. In different finfish studied to date, the timing of increase in the level of GnRH, FSH and LH depends on the optimal environmental conditions like water temperature and salinity in tropical countries like India. Specifically, LH rise in the blood takes place in response to increased GnRH expression in the brain. This takes place during specific time period like onset of monsoon rain and change in water current pattern. Increased GnRH and GtHs level result in increased circulating sex steroids. In males, an increase in 11-ketotestosterone and 17α,20β-*dihydroxy*-4-pregnen-3-one takes place during the final stages of spermatogenesis. Similarly, in females estradiol-17β, 17α,20β-*dihydroxy*-4-pregnen-3-one peaks at the end of oogeensis and onset of final oocyte maturation. Also, during spawning a surge in LH level result in elevated level of 17α,20β-*dihydroxy*-4-pregnen-3-one resulting in successful mating and spawning under natural conditions. In cultured fish, hormonal preparations are used to overcome the problems of low level of these hormones in circulating blood. Based on the experimental analysis of steroid levels in the blood, suitable hormonal preparation is selected and administered to fish.

**Steroid feedback mechanism in fish**

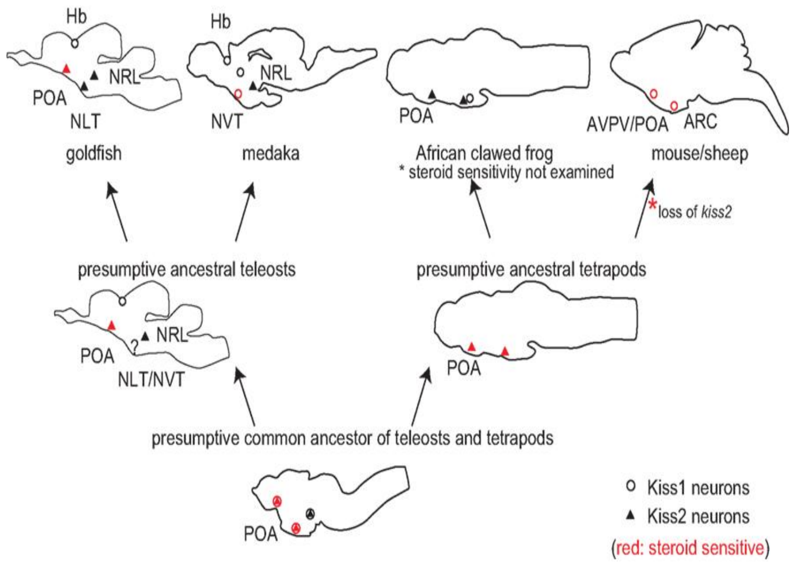
It is shown that the release of pituitary GtHs are regulated through a system of negative feedback, in which reproductive centres in the hypothalamus/pituitary are responsive to the level of circulating gonadal steroid hormones. This steroid hormones comprises mainly of testosterone, 11-ketotestosterone, 17α,20β-*dihydroxy*-4-pregnen-3-one in males; testosterone, estradiol-17β, 17α,20β-*dihydroxy*-4-pregnen-3-one in females. A rise in the level of circulating sex steroids brings about a decrease in GtHs secretion; with the result the steroid release again falls to the appropriate level (negative feedback). Simialrly, a drop in the steroid level has the opposite effect; a decrease in the steroid level brings about an increase in the level of GtHs (positive feedback). This negative and feedback mechanism is essnetial for maintaining reproductive homeostasis in fish. A number of neuropeptides are involved in regulating the negative and positive feedback in fish as shown in the picture below. In natural fish population, steroid feedback mechanism operates normally and maintains homeostasis. In cultured fish, dysfunction at the level of steroid feedback takes place at different levels.




Schematic representation of negative and positive feedback in finfish (Source: Kitahashi et al., 2013)

**Kisspeptin as regulator of steroid feedback in fish**

Kisspeptin is a neuropeptide homrone of the RF-amide family, which act as an upstream regulator of BPG axis. Kisspeptins are attributed to be key factors in mediating gonadal sex steroid feedback in fish hypothalamus. Specifically, kisspeptin neurons localized in the nucleus recessus lateralis (NRL) of hypothalamus mediate sex steroid feedback in fish like medaka. Also, demonstrated in zebrafish and goldfish. Administration of synthetic kissppetin peptides may modulate steroid feedback in cultured finfish and promote gametogenesis in fish. In medaka, steroid sensitive kisspeptin neurons in hypothalamus mediate estradiol positive feedback.




In conclusion, a basic understanding of natural breeding is essential to formulate novel inducing agents for successful captive maturation and spawning of aquacultured fish. In recent years, due to climate change cultured fish experience different types of non-conducive environmental conditions which would result in failure of fish to undergo seasonal reproduction. In light of the above, it is essential to understand the different aspects of natural breeding.

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# NUTRIENT MANAGEMENT IN INDIAN MUSTARD (*Brassica juncea L.*)

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## Introduction

Mustard seed is an important oilseed crop grown during the rabi (winter) season during September-October and harvested in February-March. The mustard seed production, which stood at 8.6 million tons in 2020-21, has increased to 8.80 million tons in the year 2022-23. Only around one-third of the fertilizer needed for oilseed crops is actually applied in India, which causes oilseeds to continuously extract nutrients from the soil (Sudhakara Babu and Hegde 2011). One of the most important aspects of growing mustard crops is managing nutrients. It entails making the best use of fertilizers and other soil amendments to guarantee that the mustard plant gets the nutrients it needs for development and yield. Rainfed farming on marginal soils and inadequate fertilizer application are the primary causes of the relatively poor productivity of mustard, Brassica juncea (L.). Thus, there is urgent need for stepping up use of deficient major, secondary and micronutrients (Hegde and Sudhakara Babu 2009). Nutrient management in mustard crop farming involves various practices, including soil testing, fertilization, fertilizer placement, crop rotation, and incorporation of organic matter.

In mustard crop farming, the first step in managing nutrients is soil testing. The availability of soil nutrients to plants and their current state can be ascertained by soil testing. The levels of organic matter, nitrogen, potassium, and phosphorus, as well as the pH of the soil, are measured. The type and quantity of fertilizer and soil amendments that farmers should apply are determined by the findings of the soil test. In the cultivation of mustard crops, fertilization is crucial since it gives the plant the nutrients it needs. Depending on plant needs, soil test findings, and other field-specific variables, different fertilizers should be applied in different amounts and types. Another crucial component of nutrient management in the production of mustard crops is the placement of fertilizer. The nutrients are guaranteed to reach the plant roots when fertilizer is applied properly. It is possible to apply fertilizer as a band, side-dressing, or broadcast. For mustard crops, a band treatment is recommended to help the roots absorb nutrients. Crop rotation is also crucial for managing nutrients in the production of mustard crops. Farmers can increase soil fertility, decrease soil-borne illnesses, and improve soil health by rotating their crops. Because legumes fix nitrogen from the atmosphere and add organic matter to the soil, rotating mustard crops with legumes like beans, peas, and clover increases soil fertility. Adding organic matter to the soil is another crucial method for managing nutrients when growing mustard crops. Organic matter enhances the soil's structure, water-holding ability, and supply of vital nutrients. Manure, compost, cover crops, and green manure are examples of sources of organic matter.

Due to unwise and unbalanced use of chemical fertilizers, soil fertility has declined in many parts of the country. The level of organic matter in the soil has also reduced considerably. According to surveys, the main nutrients - nitrogen 90 percent, phosphorus 80 percent, and potash 50 percent were found to be less. Similarly, among secondary and micro nutrients, sulphur 41 percent, zinc 40 percent, boron 33 percent, molybdenum 13 percent, iron 12 percent, manganese 5 percent and copper 3 percent were found less. Mustard plant requires a well-balanced supply of primary nutrients such as nitrogen, phosphorus, and potassium, which play vital roles in processes ranging from energy metabolism and photosynthesis to water regulation and disease resistance. Various minor and micronutrients play an important role in the production of mustard and mustard crops. A proverb about micronutrients can be said as 'They may look small but cause serious wounds'. That is, these are such nutrients which are required by plants in less than one part in a million. The incidence of deficiency of these nutrients has increased these days because out of the 17 essential elements for plants, farmers provide only the much talked about nitrogen, phosphorus and potash in the form of fertilizers and hardly use other nutrients in the crop. Thus, based on soil testing report, managing these secondary and micro nutrients effectively is the key to achieving high yields and quality in mustard cultivation.

**Secondary nutrient deficiency symptoms and their management**

**Sulphur (S)**

Mustard has a high requirement for sulfur, which is essential for the synthesis of oils and certain amino acids in the plant. Symptoms of its deficiency are first seen on new leaves and later the entire plant turns yellow. Chlorosis formation from leaf margins, spreading inward and/or develop purple pigmentation. Pods are borne on short peduncle and their development is restricted. Seed setting is poor and their maturity is delayed. Sulphur deficient plants show marked retardation in height, thickness of stem and size of leaves.

Sulphur deficiency symptoms in rapeseed mustard

**Calcium (Ca)**

Calcium is important for cell wall strength and proper cell division. Due to its deficiency, new leaves curl and shrink from the edges and the leading bud dries up and growth of roots is also reduced.

Calcium deficiency symptoms in rapeseed mustard

**Magnesium (Mg)**

Magnesium is crucial for chlorophyll production and photosynthesis. Due to its deficiency, the leaves become smaller in size and start curling upwards. The area between the main veins of the leaves in crops starts turning yellow.

Magnesium deficiency symptoms in rapeseed mustard

**Correction measure:** Generally, among secondary nutrients, sulphur deficiency has been found in the soil of our country. Fertilizers containing sulphur should be used regularly to increase the oil content in mustard seeds. Therefore, fertilizers containing sulphur nutrients such as gypsum, single super phosphate or ammonium sulphate should be used before sowing. If these cannot be used at the time of sowing, then spray a solution of a fertilizer called thia urea on the mustard crop during the flowering stage. For this, prepare a solution of 500 grams/ha of thio-urea fertilizer by mixing it in 500 liters of water and spray it on the mustard crop after 45 and 60 days. Thio-urea contains 42 percent copper and 37 percent nitrogen nutrients. This can increase the yield of mustard and the oil content in the seed. For more effect, it is advisable to spray thio-urea in second half of the day.

**Micronutrient deficiencies symptoms and their management**

**Zinc (Zn)**

Zinc deficiency symptom in many plants appears in four week old plant on older and emerging leaves. There are stunted growth and light green yellow or bleached spots in interveinal area of older leaves. The emerging leaves become smaller in size and often termed as 'little leaf'. During severe deficiency intermodal distance become too short so it appears that it come out from the same point, which is termed as 'rosetting'. Zinc is used to make a growth hormone called auxin in plants. It helps in increasing the length and width of plants. The interveinal area of sub terminal leaves develop light brown necrotic patches in Indian mustard. In mustard, it helps in increasing the quantity of pods. In Indian soils, Zn deficiency is expected to increase from 42 percent in 1970 to 63 percent by 2025 due to continuous depletion of soil fertility (Singh, 2011).

Zinc deficiency symptoms in Brassica

**Correction measure**

Based on experiments, adding zinc to zinc deficient soil increases the yield by about 25-30%. For this, 25 kg zinc sulphate per hectare can be used alone or with organic manure before sowing in the soil. This is sufficient for 3 to 4 crops. Apart from this, 0.5% zinc sulphate can be used with 0.25% slaked lime in the form of 2 or 3 sprays at an interval of 10 to 15 days depending on the severity of zinc deficiency.

**Boron (B)**

It is needed to transport the sugar produced by photosynthesis to other parts of the plant. Boron is needed during the reproductive period of the plant. If it is lacking, then the number of grains in the pods of mustard and mustard seeds decreases considerably when they flower. Due to lack of boron, the upper part of the plant dies and leaves start sprouting near it, due to which it starts looking like a bush.

Boron deficiency symptoms in rapeseed mustard

**Correction measure**

When 10 kg of borax is mixed into the fields before to sowing at a rate of one hectare, good results are achieved.

**Copper (Cu)**

It helps in making vitamin A. Its deficiency is mostly found in light soil. When symptoms of copper deficiency appear, the tips of the leaves become white and the leaves shrink and become crooked. Inflorescence is very poorly developed and large percentages of the floral buds of the plants wither before opening. Pod formation and seed setting are also reduced. In case of its deficiency, 15 kg of copper sulphate should be mixed in the soil per hectare before sowing. After the symptoms appear, spray of 0.2% copper sulphate solution 2-3 times at weekly intervals.

**Manganese (Mn)**

Various enzymatic activities in plants are inhibited by its deficiency. Due to manganese deficiency, yellowing occurs at the base of the middle leaves and spreads to their tips. For this, 25-30 kg manganese sulphate should be added to the soil before sowing at the rate of per hectare. If symptoms start appearing, then 2 or 3 sprays of 0.5% manganese sulphate dust are sufficient.

**Molybdenum (Mo)**

The symptoms of its deficiency appear early in legume crops and mustard plants. Mustard is very susceptible to molybdenum deficiency. Growth is markedly reduced and plants develop foliar symptoms like cupping, marginal scorching and loss of lamina. To overcome this deficiency, 20-25 kg/hectare molybdenum sulphate should be used.

**Conclusion**

Environmental problems such nutrient runoff, soil erosion, and disturbance of regional ecosystems can result from the careless application of chemical fertilisers.Thus, nutrient management is crucial in mustard crop farming for optimum yield and profitability. Practices such as soil testing, fertilization, fertilizer placement, crop rotation, and incorporation of organic matter can improve soil health, productivity, and sustainability. Therefore, a sustainable approach to nutrient management, often involving the use of organic amendments such as manure, compost, or green manures, is essential. These organic inputs not only supply necessary nutrients but also improve soil structure, enhance moisture retention, and foster beneficial microbial activity, thereby improving the overall fertility and health of the soil.

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# OVERVIEW OF MARINE-DERIVED ANTIMICROBIAL AGENTS : FUNGI, ALGAE, AND INVERTEBRATES

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**Abstract**
The marine environment is a rich source of bioactive compounds with significant therapeutic potential, particularly for developing antimicrobial agents. This article examines the diverse origins of these compounds, focusing on marine fungi, algae, and invertebrates. Marine fungi produce secondary metabolites, including alkaloids and polyketides, which exhibit antibacterial properties against pathogens like Candida albicans and Trichophyton rubrum. Their mechanisms of action include inhibiting cell growth, blocking efflux pumps, and disrupting biofilms. Similarly, marine algae, comprising macroalgae and microalgae, generate potent antimicrobial substances such as phlorotannins and sulfated polysaccharides that inhibit bacterial growth and biofilm formation. Additionally, marine invertebrates like sponges and tunicates provide unique antimicrobial compounds effective against multidrug-resistant strains. The mechanisms of these compounds involve disrupting cell membranes and interfering with metabolic processes. The exploration of these marine-derived substances promises to address antibiotic resistance while enhancing immune responses, paving the way for innovative applications in pharmaceuticals and functional foods aimed at improving health outcomes.

**Keywords:** Alkaloids, biofilm formation, anti-infective drugs, therapeutic applications

## Introduction

Potential medications can be found in abundance in marine species. Although there are many bioactive resources in the marine environment, not much research has looked at how these resources can alter the immune response. Proteins, peptides, and protein hydrolysates originating from marine sources have a variety of physiological properties, including antibacterial, anticancer, antioxidant, antihypertensive, and anti-inflammatory properties. Marine fungi represent a promising and largely underexplored source of bioactive compounds with significant antibacterial properties. These fungi, found in various marine environments, produce an array of secondary metabolites such as alkaloids, polyketides, and polyphenols, which are crucial in the development of anti-infective drugs targeting resistant pathogens. Notably, genera like Aspergillus and Neosartorya have been extensively researched for their ability to synthesize these valuable substances. The antimicrobial effects of marine-derived fungal metabolites occur through several mechanisms: they inhibit the growth of pathogens like Candida albicans and Trichophyton rubrum, block bacterial efflux pumps to enhance antibiotic efficacy, and prevent biofilm formation, which is essential for the virulence of many pathogens. This exploration into marine fungi highlights their potential as sources of new therapeutic agents, particularly in addressing the urgent challenge of antibiotic resistance globally.

## Marine-derived anti-microbial agents:

a) **Fungi :** Fungi derived from the sea are an intriguing source of bioactive substances, some of which have antibacterial properties (Durães et al., 2021). Fungi with marine origins are a significant and abundant source of secondary metabolites that can be used to create anti-infective drugs. Alkaloids, polyketides, coumarins, polyphenols, acetophenones, and xanthones are among the compounds that have been isolated from fungi that are derived from the sea (Sun et al., 2009; Wu et al., 2015; Sun et al., 2018; Liu et al., 2019; Wang et al., 2021). The ability of the Aspergillus and Neosartorya genera to create bioactive substances has been thoroughly investigated and identified (Lee et al., 2013; Sun et al., 2019; Huang et al., 2020; Orfali et al., 2021).

**Mechanisms of Action:**

Marine-derived fungal metabolites can act through several mechanisms:

- **Inhibition of Cell Growth:** Many compounds directly inhibit the growth of pathogens such as *Candida albicans* and *Trichophyton rubrum*.
- **Efflux Pump Inhibition:** Certain metabolites can block bacterial efflux pumps, enhancing the efficacy of existing antibiotics against resistant strains (Chin et al., 2021)
- **Biofilm Disruption:** Compounds from marine fungi have shown the ability to prevent biofilm formation, which is crucial for the virulence of many pathogens (Durães et al., 2021)

b) **Algae:** Marine, freshwater, soil, and airborne habitats are among the aquatic and terrestrial settings where microalgae can be found. The phylogenetic and evolutionary diversity of microalgae includes both eukaryotic and prokaryotic cyanobacteria (Koller et al., 2014). Through a few metabolic pathways, they produce secondary metabolites as defense mechanisms against viruses, herbivores, predation, competition for space, and adaptive methods to changes in the environment (Gacheva et al., 2014).

**Types of Marine Algae and Their Antimicrobial Properties:**

✓ **Macroalgae:**

- **Brown Algae (Phaeophyceae):** Species like *Sargassum* and *Fucus* produce phlorotannins and polysaccharides that demonstrate strong antimicrobial effects against pathogens such as *Staphylococcus aureus* and *Escherichia coli* (Silva et al., 2020).
- **Red Algae (Rhodophyceae):** Extracts from red algae contain sulfated polysaccharides and other compounds that inhibit bacterial growth, including notable activity against Pseudomonas aeruginosa (Pérez et al., 2016).
- **Green Algae (Chlorophyceae):** Compounds derived from green algae, such as carotenoids and phenolic substances, have shown antimicrobial activity against various bacteria.

**Mechanisms of Action:**

Marine algal extracts exert their antimicrobial effects through several mechanisms. The first is the inhibition of cell growth, which is when many algal compounds disrupt bacterial cell wall synthesis or interfere with essential metabolic pathways. Biofilm Disruption: Marine algae-derived compounds can inhibit biofilm formation by disrupting quorum-sensing mechanisms in bacteria, which is crucial for the virulence of many pathogens (Behzadnia et al., 2024). Synergistic Effects: Some studies indicate that algal extracts can enhance the effectiveness of conventional antibiotics when used in combination, making them valuable in the fight against antibiotic-resistant strains.

c) **Marine invertebrates :** Marine invertebrates, including sponges, tunicates, cnidarians, and molluscs, are recognized as significant sources of antimicrobial compounds. These organisms often host diverse communities of symbiotic microorganisms that produce bioactive metabolites with potential therapeutic applications.

**Key Sources of Antimicrobial Compounds**

- **Sponges:** Sponges are well-known for their rich chemical diversity, producing various secondary metabolites that exhibit antimicrobial properties. Compounds isolated from sponges have shown effectiveness against a range of pathogens, including Staphylococcus aureus and Escherichia coli (Devkar et al., 2020)
- **Tunicates:** Tunicates, or sea squirts, also contribute to the discovery of novel antimicrobial agents. Their extracts contain unique compounds that have demonstrated antibacterial activity against resistant strains of bacteria.
- **Cnidarians:** This group includes jellyfish and corals, which have been found to produce antimicrobial peptides that can inhibit microbial growth.
- **Molluscs:** Molluscs secrete mucus that contains antimicrobial substances. For instance, the mucus from the parchment tube worm Myxicola infundibulum has been studied for its lysozyme-like activity and antioxidant properties, suggesting its potential as a source of new antibiotics

**Examples of Antimicrobial Compounds:**

- ✓ **Siphonocholin:** Isolated from the red marine sponge *Siphonochalina siphonella*, this compound has demonstrated significant antibacterial activity against multidrug-resistant strains by inhibiting biofilm formation.
- ✓ **Callyaerins:** These cyclic peptides derived from *Callyspongia aerizusa* exhibit broad-spectrum antibacterial activity against various Gram-negative bacteria
- ✓ **Brominated Alkaloids:** Found in various marine sponges, these compounds have shown potent activity against resistant strains, often through mechanisms that involve disrupting cellular processes or structures (Liu et al., 2016)

**Conclusion**

The exploration of marine-derived antimicrobial compounds from fungi, algae, and invertebrates reveals a vast potential for developing new therapeutic agents. The unique bioactive metabolites produced by these organisms not only combat infections but also hold promise for enhancing immune responses. As research continues to uncover the diverse mechanisms by which these compounds operate, there is significant potential for their application in pharmaceuticals and functional foods aimed at improving health outcomes and addressing the challenges posed by antibiotic resistance. The integration of marine bioactive compounds into modern medicine could lead to innovative solutions for treating various infectious diseases while promoting overall health.

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# PLANT NUTRIENTS IN CROP PRODUCTION: THEIR ROLES, DEFICIENCY SYMPTOMS AND CORRECTIVE MEASURES

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**Abstract**

Plants require 14 mineral elements for normal growth and reproduction apart from carbon, hydrogen and oxygen which become available from air and water. Each of these nutrients has a function in plants and is required in varying amounts in plant tissue. Because of undersupply of nutrients from the soil to plants, they show characteristic symptoms of deficiency. This paper aims at highlighting their roles, deficiency symptoms and corrective measures.

## Introduction

An important part of crop farming is being able to identify and prevent plant nutrient deficiencies and toxicities. Plants require 14 mineral elements for normal growth and reproduction. Each of these nutrients has a function in plants and is required in varying amounts in plant tissue (Table 1). Macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulphur) are required in the largest amounts. Micronutrients (iron, copper, manganese, zinc, boron, molybdenum, chlorine and nickel) are required in relatively smaller amounts in plants. Other mineral elements that are beneficial to some plants but are not considered essential include sodium, cobalt, vanadium, selenium, aluminum and silicon. This paper provides background information on the nature and development of crop nutrient disorders under the growing conditions commonly encountered in India and guides us to identifying crop nutrient problems through observable symptoms on crop plants. A deficiency occurs when an essential element is not available in sufficient quantity to meet the needs of the growing plant. Nutrient toxicity occurs when an element is in excess of plant needs and decreases plant growth or quality. Nutrient deficiency or toxicity symptoms often differ among species and varieties of plants.

**Table 1. Essential plant nutrients.**

| Name | Chemical symbol | Relative % in plant* | Function in plant | Nutrient category |
|---|---|---|---|---|
| Nitrogen | N | 100 | Proteins, amino acids | |
| Phosphorus | P | 6 | Nucleic acids, ATP | Primary |
| | | | | macronutrients |
| Potassium | K | 25 | Catalyst, ion transport | |
| Calcium | Ca | 12.5 | Cell wall component | |
| Magnesium | Mg | 8 | Part of chlorophyll | Secondary |
| | | | | macronutrients |

| Name | Chemical symbol | Relative % in plant* | Function in plant | Nutrient category |
|---|---|---|---|---|
| sulphur | S | 3 | Amino acids | |
| Boron | B | 0.2 | Cell wall component | |
| Chlorine | Cl | 0.3 | Photosynthesis reactions | |
| Copper | Cu | 0.01 | Component of enzymes | |
| Iron | Fe | 0.2 | Chlorophyll synthesis | |
| | | | | Micronutrients |
| Manganese | Mn | 0.1 | Activates enzymes | |
| Molybdenum | Mo | 0.0001 | Involved in N fixation | |
| Nickel | Ni | 0.001 | Component of enzymes | |
| Zinc | Zn | 0.03 | Activates enzymes | |

*Relative amounts of mineral elements compared to nitrogen in dry shoot tissue. May vary depending on plant species.

**Occurrence of Plant Nutrient Deficiency**

A deficiency occurs when an essential element is not available in sufficient quantity to meet the needs of the growing plant. Nutrient toxicity occurs when an element is in excess of plant needs and decreases plant growth or quality. Nutrient deficiency or toxicity symptoms often differ among species and varieties of plants. The occurrence of nutrient deficiencies or toxicities is a result of soil, crop, climatic, and cultural factors. Soil properties influence the form, amount, retention and movement of soil nutrients. The effects of soil properties on water availability also influence nutrient availability, because water is essential for chemical reactions, biological activity, and the transport and absorption of nutrients by roots. Among the critical soil chemical properties affecting soil nutrient availability are soil pH (a measure of the acidity or alkalinity of a soil) and soil cation exchange capacity (a measure of the capacity of the soil to retain positively charged nutrient ions). Some important physical proper- ties affecting nutrient availability are soil texture (the proportion of sand, silt and clay-sized particles in a soil), clay mineralogy (the type of soil clay), and soil structure (the physical arrangement of soil particles). These factors interact to influence the availability of nutrients to crop plants over the course of a growing season. The soils of India vary widely in their inherent soil fertility and suitability for crop production. The most common deficiencies observed very widely are that of nitrogen, phosphorus, potassium, sulphur, magnesium, calcium, zinc, boron and iron.

When inspecting plants for symptoms of nutrient disorders, compare plants displaying symptoms with normal ones and examine new and older leaves. Nutrient deficiencies generally appear first in the oldest leaves when nitrogen, phosphorus, potassium, and magnesium are limiting. These nutrients move from one part of the plant to another as needed. Younger leaves and terminal buds show a deficiency when sulphur, iron, calcium, zinc copper, boron, manganese or chlorine are limiting. These nutrients do not readily move about in the plant. As a deficiency becomes more severe, visual symptoms may spread to the whole plant, leaves may become more chlorotic or bleached in appearance, or stunting, deformity and death of plant parts may become more extensive. Deficiencies of certain nutrients, such as sulphur and phosphorus in corn, may also be visible only early in the growing season because of immature root development or cold weather, and then become less apparent as the plant matures and the weather warms up.

**Macronutrients**

***N***

***itrogen (N):*** Because N provides green vegetation color (chlorophyll pigment), the main signs of nutrient deficiency in plants are pale-green newer and yellowish mature leaves. Unchecked early signs develop into poor secondary shooting, purple stem striping, crop thinning, or stunting. V-shaped yellowing or glossy kernels are specific signs of N deficiency in maize (**Figure 1**).

Figure 1. Nitrogen deficiency in maize

***Phosphorus (P):*** Crops need phosphorus to build proteins, buds, seeds, and blooms. A typical signal of phosphorus nutrient deficiency in plants is bronzish, purplish, or reddish coloring in the lower parts of mature foliage.

Sometimes, severe starvation results in brownish dotting and necrosis (**Figure 2**). P deficiency in grain crops (e.g., wheat) results in poor tillering.

Figure 2. Phosphorus deficiency in sorghum (left), tomato (middle), maize (right) guava (bottom)

***Potassium (K)*:** Using K, crops resist diseases and make sugars to synthesize proteins, duplicate cells, or develop roots. Potassium nutrient deficiency in plants reveals irreparable leaf-margin yellowing, rotting, scorching, crinkling, curling, shrinking, and necrosis of midribs. Potassium-deficient rice will have yellow or brown areas on leaf tips and edges. Potassium deficiency in wheat may be identified as scorched leaf tips resembling potassium deficiency, but the rest of the plants will usually be of normal size and color (**Figure 3**).

Figure 3. First Row: Potassium-deficient rice (left), maize (right); Second Row: potato (left) and soybean (right)

***Sulphur (S):*** Sulphur nutrition promotes nitrogen use and the creation of chlorophyll and proteins. Pale-green to dark-yellow new foliage is a common plant nutrient deficiency symptom because of inadequate supply of sulphur. In some crops, foliage may roll and turn purplish (typical for rape seed and mustard, tomato etc.) (**Figure 4**)

Figure 4. First Row: Sulphur deficiency in maize (left) and pea (right); Second Row: groundnut (left) and cotton (right)

Plant nutrient deficiencies for N or S are diagnosed by similar signs of yellowing, so it is critical to notice if the problem starts on newer or mature leaves.

***Calcium (Ca):*** This nutrient assists in forming new cells. For this reason, weak growth points are a distinguishing symptom of Ca nutrient deficiency in a plant: tip burns, malformation of newly-grown parts, blossom-end rots, flower drops and small fruits. Symptoms of calcium deficiency in tomatoes appear on the bottom part of the fruit**,** with dark rings and dimpling of the skin. It is the disease known as Blossom End Rot. In other organs of the plant, it causes the slight upward curling of leaves, stunted plant growth or cracked fruit, when also compounded by other factors such as water stress (**Figure 5**).

Figure 5. Calcium deficiency, First Row: maize (left) and tomato plants (right);
Second Row: tomato fruits (bottom)

***Magnesium (Mg)*****:** Magnesium deficiency usually manifests itself as interveinal chlorosis of the older leaves. In case of severe attack, the chlorosis progresses towards the interior of the leaf and the tissues turn yellow giving a rough and deformed appearance to the leaf which eventually necroses and falls off. The growth of the plant suffers and although it can still flower the formation and ripening of the fruits are compromised, the latter becoming soft. (**Figure 6).**

Figure 6. Magnesium deficiency: First Row: maize (left), cotton (right): Second Row: soybean (left) and tomato (right)

Magnesium is more easily leached than potassium because it is less well retained by clays. This fertilizer is extremely soluble so it is easily leached, it will have to be used with care to avoid the cure being worse than the disease. A generous supply of organic matter in the form of manure/compost/mulch, rich in nutrients, which help to weigh down the soil and make it less prone to leaching. Magnesium oxide can also be used as it has the ability to release the nutrient slowly. Magnesium sulfate or Epsom salt applied as a foliar spray is also a solution. Note that the latter is recommended in order to curb the appearance of black bottoms, at a dosage of 5 gr/l in bi-monthly foliar application.

**Micronutrients**

***Zinc (Zn)*:** Zinc is necessary for the development of carbohydrates, proteins, and chlorophyll. Soils lacking Zn can reduce plant growth and yield potential. Narrow yellow or white stripes between veins of upper leaves. Zinc deficiency causes yellow stripes in the upper corn leaves. **(Figure 7).** Stripes may join together to form a bleached area between midrib and leaf margins, which remain green. Zinc deficiency in rice, in local parlance known as *Khaira* disease usually occurs *at the nursery stage* due to under supply of *zinc.* The tip of the zinc deficient leaves *first become yellow* It can be identified by the *appearance of rust colored or brownish red coloration on the surface of the outer leaves. and then dry and plant remained stunted .*

Figure 7. Zinc deficiency rice (left) and maize (right)

***Copper (Cu):*** Copper is relatively immobile in plants and deficiency symptoms first appear in younger plant tissues. Its deficiency is more likely to occur in cereal grains, like wheat, barley and oat when grown on copper deficient soils. Some vegetable crops such as onions, lettuce and carrots are sensitive to copper deficiency. Evidence of copper deficiency has appeared when small grains are grown on organic soils. Symptoms appear as a general light green to yellow color in the small grain crop. The leaf tips die back and the tips are twisted. If copper deficiency is severe, growth stops and plants die after reaching the growth stage of tiller formation. In case of severe copper deficiency wheat may not produce grain in the head. In mature stands, copper deficiency can be seen in purplish brown patches, which are signs of melanosis. In maize, deficiency first appears on new leaves as they come out of the whorl and develop a bluish green tint. New leaves may emerge from the whorl as spiralled. Necrosis may occur on older leaf-tips and edges and may die. In vegetable crops, young leaves may turn bluish-green before turning yellow. The upper portion of the plant wilts; the growing point is stunted and eventually dies. The plants often fail to flower. Evidence of copper deficiency has appeared when small grains are grown on organic soils (**Figure 8**).

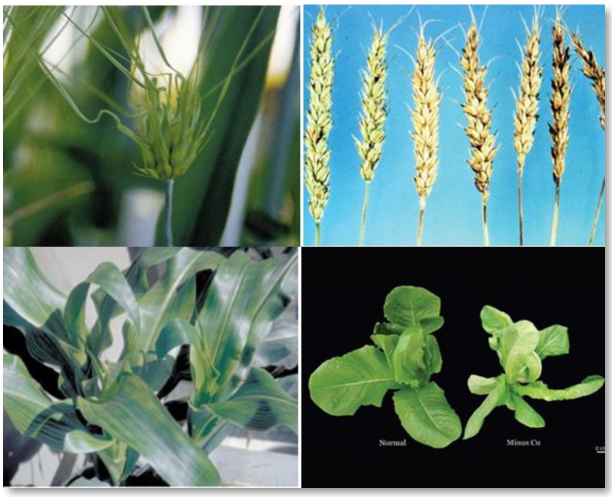


Figure 8. Copper deficiency: First Row: wheat plant (left) and ears (right). Second Row: Maize (left) and lettuce (right). Lettuce plant on the right shows deficiency and on left non-deficient plant.

***Manganese (Mn):*** Manganese plays a vital role in photosynthesis through chloroplast formation, which is important for chlorophyll development, helps in the development of carbohydrates, and influences enzyme activity. The predominant symptom is interveinal chlorosis on younger leaves (dark green veins with yellow areas between the veins of leaf). As the deficiency becomes more acute, the symptoms progress up the plant. Chlorotic leaves generally turn red and then develop spotted necrotic areas **(Figure 9).**

Figure 9. Manganese deficiency in soybean (left) and groundnut (left)

***Iron (Fe):*** Iron is needed for chlorophyll synthesis (in all crops) and nodule formation in legumes. High levels of Mn can induce Fe deficiencies and vice versa. Iron deficiency leads to chlorosis or yellowing between veins (**Figure 10**).

Figure 10. Iron deficiency in potato (left), groundnut (middle) and soybean (right)

***Boron (B):*** Boron is necessary for nodulation as it accelerates atmospheric N fixation. Deficiency appears as yellowed leaves with curled leaf tips, interveinal chlorosis, tip dieback, and stunted roots (Figure 7). Flowering can stop under severe deficiency conditions. The deficiency of boron is more common in alfalfa than in other legumes. Now boron deficiency is being widely observed in vegetable crops. The upper leaves show the symptom of curling, uneven surface and unusual hard structure (**Figures 11**).

Figure 11. Boron deficiency causes reddening of upper leaves in Egyptian clover (left) and curling of upper leaves in tomato and other vegetable crops

***Molybdenum (Mo)*****:** Molybdenum is vital for N fixation and nitrate reduction processes. If a deficiency occurs, plants have the same light-green appearance associated with N deficiency because the plants have few or no N producing nodules. Cauliflower is a indicator crop of Mo deficiency. Symptoms begin at the younger leaves. Distorted leaves with reduced leaf area and chlorotic leaf margins, "Whiptail" like formation are the characteristic symptoms of Mo deficiency in cauliflower (**Figure 12**).

Figure 12. Molybdenum deficiency in cauliflower.

**Corrective Measures:**
A description of nutrient wise corrective measures of the deficiencies is provided in **Table 2.**

**Table 2. Nutrient wise corrective measures of the deficiency in crops**

| | |
|---|---|
| **Nitrogen (N)** | Replenish phosphorus undersupply with foliar spray of IFFCO Nano Urea Plus @ 4 ml/litre water in standing crops. Application of N-containing fertilizers is a short-term method of the cure of nitrogen deficiency. Use organic matter, semi-liquid animal and green manure, blood meal, N-fixing crops and rhizobium culture to cure in plant nitrogen deficiency long-term solutions. Application of IFFCO NPK Consortia would help improving N availability apart from P and K. |
| **Phosphorus (P)** | Replenish phosphorus undersupply with seed/seedlings root treatment with IFFCO Nano DAP (8% N, 16% P2O5) @ 5 ml/kg seed or 5 ml/litre water for seedlings root treatment and then foliar spray of Nano DAP at one month @ 4 ml/litre water in seeded crops and 20-25 days in transplanted crops. Opt basal application of organic manures, crop residues, phosphatic fertilizers (DAP, NPK Complexes, Single superphosphate, water soluble fertilizers like IFFCO 0:52:34 with the recommended doses in specific crops. Application of IFFCO NPK Consortia would help improving P availability apart from N and K. |
| **Potassium (K)** | Compensate for K deficiency with muriate of potash, IFFCO natural potash (derived from molasses), water soluble potash containing fertilizers like potassium nitrate, potassium sulphate (0:0:50) etc. Take wood ash, seaweed, kelp, or poultry manure in organic farming. Application of IFFCO NPK Consortia would help improving K availability apart from N and P. |
| **Calcium (Ca)** | Use organic manures, lime, gypsum, press mud, calcium nitrate, calcium chloride. Crushed eggshells may be used as a source of Ca for crops. |
| **Magnesium (Mg)** | Foliar application of Epsom salts is a quick and short-term solution to correct Mg deficiency. Add dolomite (dolomitic limestone) to enrich the soil with Mg in the long run. Use organic manures like compost, farm yard manure, crop residues etc. |
| **sulphur (S)** | Choose IFFCO bentonite sulphur or sulphate of potash, kieserite, or magnesium/ammonium sulfate, single superphosphate, . Mind the presence of other elements in the compounds. Composted mushrooms are a popular method to address the S deficiency in organic farming. |
| **Iron (Fe)** | Correct Fe deficiency in plants by spraying ferrous sulfate @ 1% dilution for quick results. Ferrous sulphate @ 25-50 kg/ha or Iron chelate compounds (FeEDDHSA or FeEDTA) @ 10 kg/ha help solve the problem for a longer time.oliar spray be done in standing crop at early stage |
| **Zinc (Zn)** | It can be managed by application of IFFCO Zinc sulphate monohydrate @ 5 kg in the nursery area to plant in one hectare. Otherwise, foliar application would be needed @ 0.3% solution of zinc sulphate in the nursery, as well as in the standing crop depending on the need. |

| | |
|---|---|
| **Boron (B)** | Correct B deficiency with foliar spray of IFFCO Boron (Borax) containing 20% B @ 0.2-3% dilution in standing crops. Ensure soil application of IFFCO Boron (Borax) (14.5% B) @ 10 kg/ha in boron deficient soils. |
| **Copper (Cu)** | Apply copper sulphate @ 0.2% dilution for foliar spray in standing crops. Opt for soil application of copper sulphate @ 10 kg/ha as basal application in copper deficient soils. |
| **Manganese (Mn)** | Use manganese sulphate for foliar spray @ 0.5-1% dilution to cure Mn deficiency in standing crops. Opt manganese sulphate for basal application @ 20-25 kg/ha in Mn deficient soils. |
| **Molybdenum (Mo)** | Use molybdenum-containing additives (Sodium molybdate or ammonium molybdate) for foliar spray @ 0.1% dilution for foliar spray in standing crops or soil application @ 1-2 kg/ha preferably sodium molybdate, as it would be cheaper. |

**Note***:* Opting for ways to fix nutrient deficiencies, consider the correct proportions and chemical combinations ensuring the compatibility of each other to avoid fertilizer burns in your crops.

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# RADISHES: THE CRISP AND COLOURFUL STAR OF EVERY SEASON

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**Abstract**

Radishes (Raphanus sativus) are the unsung heroes of the vegetable world, offering a burst of colour, crunch, and nutritional power year-round. With their vibrant hues ranging from fiery reds to delicate whites and pinks, radishes not only add visual appeal to any dish but also serve as a rich source of essential nutrients. Their peppery bite is a signature flavour, while their health benefits, such as aiding digestion, boosting immunity, and supporting detoxification, make them an indispensable addition to a balanced diet. Radishes are an easy-to-grow, low-maintenance vegetable, thriving in diverse climates and requiring minimal care, making them perfect for gardeners of all levels. Whether enjoyed raw in salads, pickled, roasted, or incorporated into soups, radishes lend their versatility to countless culinary creations. This article celebrates radishes as the crisp and colourful star of every season, exploring their rich history, diverse varieties, cultivation tips, and transformative culinary roles. Emphasizing their multifaceted nature, radishes embody the perfect fusion of taste, health benefits, and accessibility, earning them a prominent place in both gardens and kitchens alike.

**Keywords**: Raphanus sativus, vibrant colours, nutritional power, health benefits, immunity, digestion, detoxification, culinary versatility, peppery flavour, gardening.

## Introduction

radishes (*Raphanus sativus*) are often regarded as the crisp and colourful stars of every season, offering a delightful combination of visual appeal, flavour, and nutritional benefits. These small, round or cylindrical root vegetables are packed with vibrant colours, ranging from the traditional red globe variety to the white daikon, purple, and even watermelon-shaped radishes. Their distinct peppery flavour and crunchy texture make them a staple in salads, sandwiches, and garnishes, while their low calorie and high fibre content contribute to their popularity in healthy eating regimens. Beyond their culinary versatility, radishes have a rich history of cultivation dating back thousands of years, with mentions in ancient civilizations such as Egypt, Greece, and Rome. Historically prized for their medicinal properties, radishes have been used to treat a variety of ailments, including digestive issues and respiratory ailments (USDA, 2023).

The appeal of radishes extends beyond their appearance and taste. They are packed with essential nutrients like vitamin C, potassium, fibre, and antioxidants, all of which contribute to numerous health benefits. Radishes support immune function, promote healthy digestion, detoxify the body, and even aid in weight management due to their low-calorie content and high water and fibre composition (WHO, 2022). Their health benefits, coupled with their ease of cultivation and rapid growth cycle, have made radishes a favourite among gardeners worldwide. Whether grown in small containers, raised beds, or traditional garden plots, radishes can be harvested in just a few weeks, offering a rewarding crop for even novice gardeners (The Spruce Eats, 2021).

**Varieties of Radishes**

The most common varieties are the red globe radish, but there are many other types that differ in flavour, texture, and use. Some radishes are mild and sweet, while others are peppery and sharp. Radishes come in numerous varieties, each with its colour, flavour, and size:

| Variety | Colour | Flavour | Size |
|---|---|---|---|
| Red Globe | Red | Mild | 1-2 inches |
| Daikon | White | Mild-Sweet | 6-18 inches |
| Black Radish | Black | Pungent | 3-8 inches |
| Watermelon Radish | Green-White | Sweet-Crisp | 3-5 inches |
| French Breakfast | White-Red | Spicy | 4-5 inches |

**Health Benefits of Radishes**

Radishes, known for their crisp texture and peppery flavour, are not only a delightful addition to salads and dishes but also offer various health benefits. They are low in calories and rich in essential nutrients, making them a smart choice for health-conscious individuals. Below is a summary of the notable health benefits of radishes.

**Health Benefits Overview**

| Health Benefit | Description |
|---|---|
| **Rich in Antioxidants** | Radishes contain antioxidants like vitamin C and other phytochemicals, which help protect the body from free radical damage. |
| **Supports Immune Function** | High vitamin C content boosts the immune system, promoting better overall health and disease resistance. |
| **Aids Digestion** | The dietary fibre in radishes promotes good digestion and may help prevent constipation. |
| **Hydration** | With about 95% water content, radishes contribute to hydration, making them excellent for maintaining fluid balance. |
| **Weight Management** | Low in calories but high in nutrients, radishes are filling and can help control appetite, aiding in weight management. |
| **Promotes Heart Health** | Radishes are rich in potassium, which helps regulate blood pressure and support overall cardiovascular health. |

**Nutritional Profile of Radishes**

Radishes (Raphanus sativus) are a nutritious root vegetable enjoyed for their crisp texture and peppery flavour. Per 100 grams, radishes contain approximately 16 calories, 3.4 grams of carbohydrates, and 1.6 grams of dietary fibre, making them low in calories yet filling (USDA, 2021). They also provide essential nutrients such as vitamin C (14.8 mg), which supports the immune system and skin health, and folate (25 µg), crucial for DNA synthesis and cellular function

(Healthline, 2021). Additionally, radishes are a good source of potassium (252 mg), important for heart health and blood pressure regulation (Medical News Today, 2019). With only 0.1 grams of fat and minimal sugars, radishes are an excellent addition to a balanced diet, promoting overall health and wellness.

**Various Coloured Radishes**

Radishes exhibit a wide range of colours, each of which is associated with specific roles, nutrients, and culinary uses. The diverse pigments in radishes not only enhance their visual appeal but also provide functional benefits, such as antioxidants and phytochemicals that contribute to human health.

| Radish Colour | Variety | Taste Profile | Nutritional Benefits | Culinary Uses |
|---|---|---|---|---|
| **Red** | Red Globe | Mildly spicy, crisp | Acts as an antioxidant, reduces oxidative stress, supports cardiovascular health | Salads, pickles, sandwiches |
| **White** | Daikon | Mild, slightly sweet | Mild flavour, rich in vitamin C, promotes digestion and detoxification | Soups, stir-fries, sushi |
| **Black** | Black Spanish | Strong, pungent | Antimicrobial properties, enhances liver function, aids in detoxification | Salads, grilling, pickling |
| **Purple** | Purple Plum | Spicy with sweetness | Anti-inflammatory properties, supports skin health | Salads, garnishes, roasting |
| **Pink** | Watermelon Radish | Sweet and crunchy | Combines sweetness and spice, promotes hydration, rich in antioxidants | Salads, fresh dishes, garnishes |
| **Green** | Green Radish | Mildly spicy | Supports immune health, detoxifies the body, promotes skin health | Salads, kimchi, pickling |

**Culinary Uses of Radishes**

Radishes are versatile root vegetables widely used in various culinary traditions. Their crunchy texture and peppery flavour make them an ideal addition to salads, sandwiches, and slaws. Common varieties, such as red, white, and black radishes, each offer slightly different Flavors and textures.

**(A) Raw in Salads:** Radishes are often sliced thin and added to salads for a sharp, spicy bite. They complement ingredients like lettuce, cucumbers, and herbs, often with a light dressing to balance their heat (Zhang *et al*., 2018).

**(B) Pickled:** Pickled radishes are a staple in many cuisines, particularly in Korean (e.g., *kkakdugi*) and Mexican dishes. The process of pickling tones down their spiciness while enhancing their texture, making them a perfect side dish or garnish (Lee *et al.,* 2021).

**(C) Roasted or Grilled:** Roasting or grilling radishes softens their sharpness and brings out a subtle sweetness. They are often incorporated into vegetable medleys or served as a side dish (Dewhurst, 2014).

**(D) Soups and Stews:** Radishes can be used in soups, like in Japanese *miso* soups or as part of a stew, where their flavour is mellowed by cooking, providing a unique, earthy undertone (Zhang *et al.*, 2018).

**(E) Radish Greens:** The leaves of radishes are edible and can be used in soups, salads, and as a garnish, offering a milder flavour compared to the root itself. They are also often sautéed with garlic or used in pestos (Zhang *et al*., 2018).

**Radishes in Modern Trends**

Radishes, once seen as a modest vegetable, have recently taken centre stage in modern culinary trends. Their crisp texture, vibrant colour, and wide range of Flavors—from mildly sweet to spicy—make them a versatile ingredient that fits well with current food movements, including health-conscious eating, sustainability, and culinary innovation.

**Radishes in Government and Artisanal Dishes**

- **Pickling**: Pickled radishes are a popular choice in gourmet cooking for their tangy flavour and ability to pair well with a variety of dishes, from grilled meats to tacos. Pickling enhances their natural crunch while introducing a unique acidity, making them a favourite garnish or accompaniment (Park *et al.,* 2020).
- **Roasted and Grilled Radishes**: Roasting or grilling radishes is another popular trend. The heat transforms their sharp, peppery taste into a more mellow, slightly sweet flavour. This technique is used in contemporary fine dining, where roasted radishes are often paired with other seasonal vegetables or served as a side dish (Kim, 2017).

**Radishes in Fermented Foods**

- **Radish Kimchi and Fermentation**: Radish kimchi, a type of Korean pickle made from radish and fermented with chili paste, garlic, and ginger, is gaining popularity. It is rich in beneficial bacteria that support gut health and digestion (Park *et al.,* 2020). Additionally, radishes are often used in other fermented dishes like sauerkraut and pickled vegetable medleys, offering both flavour and probiotic benefits.
- **Probiotic Benefits**: The fermentation process increases the bioavailability of nutrients in radishes, enhancing their digestive benefits and overall nutritional value. The incorporation of radishes into fermented foods is part of the broader movement toward consuming more probiotic-rich dishes for gut health (World Health Organization, 2022).

**Radishes in Cocktails and Beverages**

- **Cocktails**: Radish-infused spirits and syrups are used in creative cocktails to add an earthy, peppery kick. These drinks pair particularly well with spirits like gin, tequila, and vodka. For example, radish slices or radish juice are featured in cocktails such as martinis or margaritas, offering a unique twist on classic recipes (Sokolov, 2010).
- **Radish Juices**: Radish juice is becoming a trendy ingredient in health-focused beverages, often combined with other fruits and vegetables like apples, carrots, and cucumbers to create refreshing, detoxifying drinks. These beverages align with the growing demand for functional drinks that promote health and well-being (World Health Organization, 2022).

**Innovative Uses in Baking and Pastry**

- **Radish Bread and Pastries**: Some bakeries have begun experimenting with Savory pastries, incorporating radishes into bread or pastries. These baked goods often feature the subtle flavour of radishes, sometimes paired with herbs, cheese, or other vegetables to create a unique snack or side dish.

**Conclusion**

In conclusion, radishes are much more than just a simple garnish; they are a vibrant, nutritious, and versatile vegetable that shines throughout every season. With their crisp texture, refreshing flavour, and a variety of colours ranging from red to purple to white, radishes bring both beauty and taste to any dish. Whether used raw in salads, roasted for a mellow sweetness, or pickled for an extra tang, radishes can be incorporated into countless recipes. Packed with vitamins, minerals, and antioxidants, they support a healthy lifestyle while being low in calories. Their high fibre content promotes digestion, and their natural compounds contribute to heart health. Easy to grow and available year-round, radishes are a sustainable, flavourful choice for home cooks and chefs alike. With their unique blend of flavour, nutrition, and adaptability, radishes truly deserve their place as a star ingredient in kitchens around the world.

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# HARNESSING THE POTENTIAL OF SEAWEED BIOSTIMULANT IN FLOWER CROPS

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**Abstract**

The demand for synthetic fertilizers has rapidly increased in agriculture. The continuous use of chemical fertilizers is diminishing soil fertility, causing health threats to humans, livestock and the microbes present in the soil. To overcome this and to increase the efficiency in plant cultivation, Biostimulants like seaweed extracts can be used as fertilizers in sustainable agriculture. The seaweed suspensions or extracts obtained from the macroalgae gain commercial importance and it can be an alternative method, especially in organic farming. Seaweed biostimulants are useful for achieving higher agricultural production because these extracts contain growth-promoting hormones like Auxins, Gibberellins, Cytokinins, Abscisic acid, Ethylene, along with Betaines, Polyamines, vitamins, amino acids, antibiotics and micronutrients.

**Introduction**

The application of seaweed extracts to different crop plants is of great importance to substitute inorganic fertilizers and to reduce the cost of production. Numerous studies have revealed a wide range of beneficial effects of seaweed extract applications on plants, such as early seed germination and establishment, improved crop performance and yield, elevated resistance to biotic and abiotic stress and enhanced postharvest shelf-life of perishable products. The endogenous plant growth regulators present in the seaweed extracts and concentrates are thought to be involved in promoting plant growth and yield.

**Seaweeds**

Seaweeds are the macroalgae that constitute an integral component of marine and coastal ecosystems. These are the macroalgae are aquatic plants belonging to the plant kingdom Thallophyta and often regarded as **Wonder plants of the sea.** There are number of localities along the Indian coastline with luxuriant seaweed growth with high species diversity notably in Gujarat, Maharashtra, Tamil Nadu, Lakshadweep and Andaman and Nicobar groups of Islands.

**Seaweed Extracts:**

Seaweed extracts are the substances derived from seaweeds and have numerous positive effects on plant growth, thus have the potential to solve most of the problems that agriculture will face in the future. These are a promising class of biostimulant in sustainable agriculture and represent the fastest-growing biostimulant industry. They have various desirable, stimulatory effects on growth in plants, seeds, and crops besides maintaining soil health.

**Classification of seaweeds:**

It is estimated that seaweeds or macroalgae compromise nearly 10,000 species, which are subdivided mainly to three categories based on their pigmentation;

- Phaeophyta (Brown),
- Rhodophyta (Red), and
- Chlorophyta (Green) Brown.
- Brown seaweeds are usually large, and range from the giant kelp that is often 20 m long, to thick, leather-like seaweeds from 2-4 m long, to smaller species 30-60 cm long.
- Red seaweeds are usually smaller, generally ranging from a few centimetres to about a metre in length. However, red seaweeds are not always red, they are sometimes purple, even brownish red, but they are still classified by botanists as Rhodophyceae because of other characteristics.
- Green seaweeds are also small, with a similar size range to the red seaweeds. Seaweeds with Ascophyllum, Fucus, Laminaria are the dominant group.

**Methods of Preparation and Extraction**

Both physical methods (heat, pressure, and microwaves) and chemical methods (solvents, acids, and alkali) are used for the extraction of seaweeds. The choice of extraction method should be able to deal with the complexity of the seaweed composition and guarantee the integrity of biologically active molecules that have biostimulant value. The most widely used extraction process involves alkaline extraction at high pressure. Currently different methods are used to this purpose. Novel extraction technologies, like ultrasound-assisted extraction (UAE), enzyme-assisted extraction (EAE), supercritical fluid extraction (SFU), microwave-assisted extraction (MAE), and pressurized liquid extraction (PLE) offer the advantage of extracting biological compounds without affecting their activity.

**Mode of application of seaweeds**

The type of application depends on the **nature of the seaweed product** (eg. Meal or extract).

**Seaweed biomass and seaweed meal**

Application of whole seaweed biomass or meal is most common near coastal areas where the seaweeds are abundant. Whole seaweeds are spread on the ground and are **usually worked** into the soil to **facilitate microbial decomposition.** Seaweeds are incorporated into the soil considerable time in advance of planting crops because during the decomposition phase, soil bacteria deplete nitrogen in the soil resulting in a temporary nutrient deficiency that will negatively impact plant growth.

**Seaweed extracts:**

Available as **liquid extracts** or in a **soluble powder form**. Most application types are either foliar, root application or both. These are applied to **soil or the growing medium** through fertigation, drenching or dripping.

Liquid and powder extracts are applied near the root of the plant by mixing the extracts with irrigation water and applied as drip irrigation to crops. However, foliar sprays of less than or equal to 0.05% v/v of the extract have been reported to be optimal for the crop and result in more effective control of disease and higher yields.

**Uses of seaweed extracts:**

1. Seaweeds and seaweed extracts enhance soil health by improving moisture-holding capacity and by promoting the growth of beneficial soil microbes.
2. Brown seaweeds are rich in polyuronides such as alginates and fucoidans. The gelling and chelating abilities of these polysaccharides coupled with their hydrophilic properties make these compounds important in food processing and in the agricultural and pharmaceutical industries (Cardozo *et al.,* 2007).
3. Extracts of various marine brown algae *Laminaria japonica* and *Undaria pinnatifida* could be used as an arbuscular michorichal fungus growth promoter (Kuwada *et al.,* 2006).
4. Seaweed products promote root growth, development and improves plant mineral uptake by the roots.
5. Seaweeds products enhance plant chlorophyll content. This increase in chlorophyll content is due to a reduction in chlorophyll degradation, which might be caused in part by betaines in the seaweed extract.
6. Seaweed concentrates trigger early flowering and fruit set in a number of crop plants.
7. Plants sprayed with seaweed extracts exhibit enhanced salt and freezing tolerance (Mancuso *et al.,* 2006).
8. Seaweed extracts have been shown to enhance plant defense against pest and diseases.
9. Plants treated with seaweed extract (*Eklonia maxima*) caused a reduction in nematode infestation.

**Seaweed Cultivation**

CSMCRI and Central Marine Fisheries Institute are cultivating seaweeds (*kappaphycus alvarezii*) along the seashore in mandapam of Tamil Nadu's Rameswaram by bamboo raft method to meet the demand of the Indian seaweed industry.

**Conclusion**

Studies have shown that seaweed extracts protect plants against a number of biotic and abiotic stresses and offer potential for field application. Further, seaweed extracts are considered an organic farm input as they are environmentally friendly and safe. Their integration into popular farming practices worldwide can increase the yield of crops in a sustainable manner.

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| Green Seaweeds | Brown Seaweeds | Red Seaweeds |
|---|---|---|
|  |  |  |
| *Enteromorpha flexuosa* | *Fucus spiralis* | *Gracilaria edulis* |

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# SEWAGE TREATMENT TECHNOLOGIES: A MINI REVIEW

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**Abstract**

Eliminating contaminants from wastewater, including particles, organic carbon, nutrients, and pathogens, is the main objective of sewage treatment technology. For the sake of the environment and public health, wastewater management must be done effectively. In order to maintain the environment while taking socioeconomic and public health issues into account, treatment operations use a variety of techniques to lower water and organic content.. Effective wastewater management is crucial for protecting public health and the environment. A comprehensive approach is necessary, considering the entire wastewater treatment process. Best practices include implementing water conservation programs, using energy-efficient treatment technologies, and regularly maintaining treatment systems. Monitoring and reporting treatment performance is also essential. Additionally, implementing reuse and recycling programs can reduce wastewater discharge and promote sustainable development.

**Keyword:** Sewage, Treatment, Wastewater

## Introduction

"Sewage/Community wastewater" is the phrase used to describe wastewater that is released from residential, commercial, and institutional settings. Waste water is a combination of liquids from various sources, including nonpoint sources (such as agricultural runoff, storm and urban runoff, and atmospheric deposition) and point sources (such as industrial effluents, municipal sewage treatment, combined sewage storm water overflows, resource extraction, and land disposal sites). Technically, the solid part of sewage is called sludge, and the liquid part is called sewage water or effluent. It is organic because it contains carbon compounds such as paper, vegetable matter, human waste, and other materials, and it is composed of 99.9% water and 0.1% solids. In addition to wastewater from homes, there is wastewater from industries. A lot of industrial waste is organic as well, and it can be handled in the same way as sewage by physical, chemical, and biological processes (Topare et al., 2011).

## Evaluation of sewage impact and organic pollution measurement

Numerous chemical and biological parameters can be used to quantitatively evaluate organic pollution in water. These factors are closely linked to the amount of organic matter in the water, giving a thorough picture of the general health and pollution levels of the water. These methods are used to measure organic pollution:

- **Biochemical Oxygen Demand (BOD)**
  It is a measure of the amount of oxygen required by microorganisms to break down organic matter in a given volume of water over a specific period of time, usually five days.
- **Chemical Oxygen Demand (COD)**

It is a measure of the amount of oxygen required to break down organic matter in a given volume of water through chemical reactions.

- **Total Oxygen Demand (TOD)**
  It is a measure of the total amount of oxygen required to break down all the organic and inorganic matter present in a given volume of water

**Impacts of sewage pollution on aquatic environment**

- **Physical effects:**
  1. Water Turbidity: Sewage pollution increases water turbidity, reducing light penetration and affecting photosynthesis.
  2. Temperature Changes: Sewage can alter water temperature, affecting aquatic life and their habitats.
  3. pH Imbalance: Sewage can change the pH of the water, affecting the survival of aquatic organisms.
- **Chemical Effects:**
  1. Nutrient Pollution: Excess nutrients from sewage can stimulate algae growth, leading to eutrophication and dead zones.
  2. Toxic Chemicals: Sewage can contain toxic chemicals, such as heavy metals, pesticides, and industrial pollutants, which can harm aquatic life.
  3. Pathogens and Bacteria: Sewage can contain pathogens and bacteria, such as *E. coli* and Salmonella, which can cause waterborne diseases.
- **Biological Effects:**
  1. Changes in Aquatic Life: Sewage pollution can alter the composition of aquatic communities, leading to changes in species diversity and abundance.
  2. Harm to Aquatic Organisms: Sewage pollution can cause physical harm, such as gill damage, and biochemical changes in aquatic organisms.
  3. Disruption of Food Chains: Sewage pollution can disrupt food chains, affecting the entire aquatic ecosystem.
- **Human Health Effects:**
  1. Waterborne Diseases: Sewage pollution can cause waterborne diseases, such as cholera, typhoid, and diarrhea.
  2. Recreational Water Risks: Sewage pollution can pose health risks to people engaging in recreational water activities, such as swimming and fishing.
  3. Economic Impacts: Sewage pollution can have significant economic impacts, including losses to fisheries, tourism, and other industries.

**Why should we treat the sewage water?**

Direct release of waste water into bodies of water, which causes the water quality of those bodies to significantly decline. Waste water treatment methods were initially created in response to the negative conditions brought about by the direct discharge of waste water into bodies of water. Additionally, as the population grows, the amount of waste water produced increases quickly, and the rapidly declining quality of this massive volume of waste water surpasses the streams' and rivers' ability to purify themselves. The following factors make sewage treatment techniques crucial:

- Protection and conservation of environment.

- Reduce nutrient pollution / Eutrophication
- Improve public health & safety
- For increasing aquaculture production
- Improve water efficiency

**Sewage treatment methods**

In order to properly return the residual waste water to the river or sea and reintegrate into the natural cycle, sewage treatment involves eliminating organic and other oxygen-demanding components from the wastewater, such as suspended sediments, nutrients, fats, oil, and grease, as well as pathogens. Typically, sewage treatment consists of the following steps.

**Types of treatment process**

| S. No. | Type of treatment | Type of treatment unit | Name of the unit | Types of impurities removed |
|---|---|---|---|---|
| 1. | Physical treatment | Physical | Screen | Large suspended and floating matter |
| | | Physical | Grit chamber | Grit |
| | | Physical | Clarifiers | Slit, Sand and other heavier matter |
| 2. | Chemical treatment | Chemical | Chemical reactors | Dissolved chemicals |
| 3. | Biological treatment | Biological | -Trickling filters<br>- Activated sludge plant | Dissolved organic chemicals |

- **Preliminary Treatment**

Preliminary treatment, also known as pre-treatment, is the initial stage of wastewater treatment. Its primary objective is to remove large objects, debris, and other materials that could damage equipment, clog pipes, or interfere with subsequent treatment processes. Preliminary treatment typically involves physical processes, such as:

1. Screening: Removing large objects like sticks, rags, and plastics.
2. Grit removal: Eliminating sand, gravel, and other inorganic particles.
3. Grinding: Breaking down large objects into smaller pieces.

- **Primary Treatment**

Primary treatment is the second stage of wastewater treatment, following preliminary treatment. Its primary objective is to remove suspended solids, organic matter, and other contaminants from the wastewater through physical and chemical processes (Rogers, 1996).

Primary treatment typically involves the following processes:

1. Primary sedimentation: Wastewater is allowed to settle in large tanks, where heavier particles sink to the bottom and are removed as sludge.
2. Skimming: Floating materials, such as oils and greases, are skimmed off the surface of the water.
3. Chemical addition: Chemicals may be added to the wastewater to enhance the removal of suspended solids and organic matter.

- **Secondary Treatment**

Secondary treatment is the third stage of wastewater treatment, following primary treatment. Its primary objective is to remove organic matter and pollutants from the wastewater through biological processes (Jewell, 1987). Secondary treatment typically involves the following processes:

1. Activated Sludge Process: Microorganisms, such as bacteria and protozoa, are added to the wastewater to break down organic matter (Handel, 1994)
2. Trickling Filter Process: Wastewater is passed over a bed of media, such as rocks or plastic, where microorganisms break down organic matter.
3. Rotating Biological Contactor (RBC) Process: Wastewater is passed over a series of rotating disks, where microorganisms break down organic matter.
4. Biological Aerated Filter (BAF) Process: Wastewater is passed through a filter, where microorganisms break down organic matter.

- **Tertiary Treatment**

Tertiary treatment, also known as advanced treatment, is the fourth and final stage of wastewater treatment. Its primary objective is to further remove pollutants and contaminants from the treated effluent, producing a high-quality water that can be safely reused or discharged into the environment.

Tertiary treatment typically involves physical or chemical processes, such as:

1. Filtration: Using filters, such as sand, membranes, or ultraviolet (UV) light, to remove remaining suspended solids and contaminants.
2. Disinfection: Using disinfectants, such as chlorine, ozone, or UV light, to kill remaining bacteria, viruses, and other microorganisms.
3. Nutrient removal: Using processes, such as chemical precipitation or biological nutrient removal, to remove excess nutrients, such as nitrogen and phosphorus.
4. Advanced oxidation: Using processes, such as ozone or hydrogen peroxide, to break down and remove remaining organic contaminants (Kartal et al, 2010).

**Conclusion**

The ultimate goal of managing wastewater is to safeguard the environment and public health. To achieve this, we need to understand the nature of the wastewater and decide whether it requires primary, secondary, or tertiary treatment before being disposed of. Knowing the characteristics of wastewater is crucial for designing an effective treatment process. This involves selecting the right procedures, setting acceptable standards for treated water, and determining the level of testing required to ensure the treated water is safe and meets quality standards. Ultimately, our goal is to ensure that treated wastewater is not only safe but also effective and of high quality. This requires careful consideration of the treatment process and rigorous testing to guarantee that the treated water meets the required standards.

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# ROLE OF MICRO-ORGANISMS TO ENRICH SOIL FERTILITY

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**Abstract**

Soil fertility is an important part of sustainable agriculture, as it influences plant development, crop productivity, and ecosystem health. Microorganisms have an important role in increasing soil fertility by improving nutrient cycling, organic matter decomposition, and soil structure. Beneficial soil microflora, including bacteria, fungus, and actinomycetes, help to fix nitrogen, solubilize phosphorus, and break down complex organic compounds into accessible nutrients. Furthermore, mycorrhizal fungi create symbiotic associations with plant roots, which aids nutrient uptake, especially in nutrient-poor soils. Beneficial microbes boost soil health by inhibiting soil-borne diseases, stimulating plant growth, and preserving soil biodiversity. This paper investigates the ways by which microorganisms contribute to soil fertility and analyses their potential role in sustainable agriculture operations. Understanding and utilizing these natural soil enhancers can reduce reliance on chemical fertilizers, boosting environmental sustainability and increasing soil resilience.

**Keywords:** Soil fertility, Micro-organisms, Organic matter decomposition, Sustainable agriculture, Soil health, Soil biodiversity, Plant growth promotion.

## Introduction

Soils naturally cover the earth's surface and serve as the interface of three different material states: liquids (water), gases (air in soil pores), and solids (geological and dead biological components). The combination of geological parent material, glacial and geomorphological history, biota presence and activity, land use history, and disturbance regimes results in a specific soil composition. Soils are the foundation of all terrestrial ecosystems and support a diverse range of plants, algae, bacteria, archaea, fungi, insects, annelids, and other invertebrates. The food or nutrients provided by soil dwellers support the species that live both above and below ground. Soils also play a critical role in buffering and filtering freshwater habitats. As a result, soils are immensely vital to human societies. Humans rely on soils to support ourselves and our buildings, as well as to produce food, construction materials, and other resources. In fact, soils influence the majority of ecosystem services on which humans depend (Dominati *et al.*, 2010).

Soil microorganisms, including bacteria, archaea, and fungi, provide a variety of ecosystem services, many of which are crucial. The immense metabolic diversity of soil microorganisms drives or contributes to the cycling of all main elements (e.g., carbon [C], nitrogen [N], phosphorus [P]). These processes affect the structure and functioning of soil ecosystems as well as soils' ability to provide benefits to people.

Farmers use chemical pesticides and fertilizers to meet agricultural demands. However, these practices harm soil health and lower biodiversity. With the demand for agricultural produce expected to climb by 70% over the next 30 years, sustainable farming approaches are increasingly recognized as essential to meeting the world's agricultural needs in the future (Altieri, 2004). Soil physical and chemical qualities, such as soil organic matter content, pH, and redox potential, significantly impact the structure and dynamics of microbial communities as well as soil functions.

Soil microorganisms play a crucial role in agriculture by improving soil quality, providing plant nutrition, and maintaining plant health.

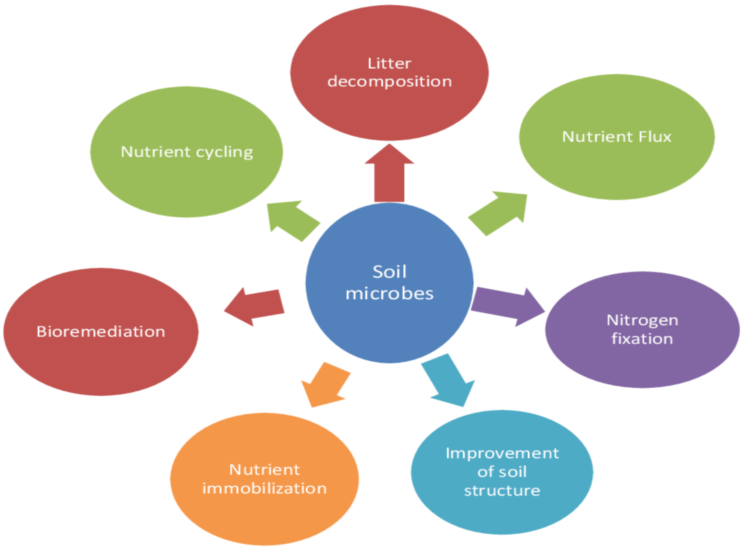
**Table 1 highlights soil microorganisms' role in providing and controlling soil ecosystem services (derived from Dominati *et al*., 2010).**

| Soil support | Descriptor | Role of soil microorganisms |
|---|---|---|
| Physical support | Soils cover the earth's surface and provide the physical foundation for animals, humans, and infrastructure. Soils also host animal species that are beneficial to humans. | Microbes contribute to soil formation by cycling nutrients and producing organic matter. |
| Raw materials | Soils can provide raw materials (such as peat for fuel and clay for potting). | Soil bacteria produce antimicrobial agents and Enzymes for biotechnological applications. |
| Nutrient cycling | Soil is the site where organic compounds decompose and nutrients are mobilized from bedrock and soil aggregates. | Soil bacteria, archaea, and fungi play important roles in nutrient cycle and mineral weathering. |
| Filtering of pollutants. | Pollutants (such as excess nutrients, foreign microorganisms, metals, and organic compounds) that drain from soils can contaminate aquatic habitats and endanger human health. Soils absorb and hold solutes and contaminants, preventing their release into the water. | Microbial products, together with clay and organic matter concentration, contribute to soil hydrophobicity and wettability, influencing soils' ability to filter pollutants. |

Most people believe that bacteria are disease-causing agents. These soil microbes will help decompose organic materials.

**Types of soil micro organisms**

**Bacteria:** Bacteria have such a simple structure that they are frequently referred to as enzyme bags or fertilizer-soluble bags. Soil bacteria play an important role in crop processing because they participate in processes that provide soil nutrients, boost plant growth (e.g., plant hormone development), regulate or inhibit plant pathogens, improve soil composition, and promote bioaccumulation and inorganic microbial leaching. Ingham (2009) categorizes soil bacteria into four functional groups: decomposers, mutualists, pathogens, and lithotrophs. Each functional bacterial type contributes to the recycling of soil nutrients. Microorganisms used to fix atmospheric nitrogen and boost the availability of nutrients, particularly nitrogen. In addition to its vital role in food production and plant growth (Pandey *et al*., 2020), nitrogen is required for the synthesis of proteins, RNA, DNA, chlorophyll, and cellular enzymes. Bacteria known as "Rhizobia" are thought to cause nodules at the roots of leguminous plants (and, rarely, stalks). The different "bacteroid" kinds aid in the fixation of nitrogen from the atmosphere within those nodules, and ammonia is then employed as a fixed nitrogen source. This symbiotic connection provides an exceptional niche for a bacterium, while the plants benefit from a specific supply of nitrogen.




**Actinomycetes:** Actinomycetes are gram-positive aerobic bacteria classified by their substrate and aerial mycelium development. They create connections with some non-leguminous plants and fix nitrogen, making it available to both the host and other plants in the neighbourhood. Actinomycetes live in the rhizosphere of agricultural crops, where they improve soil fertility by recycling organic materials and solubilizing phosphate.

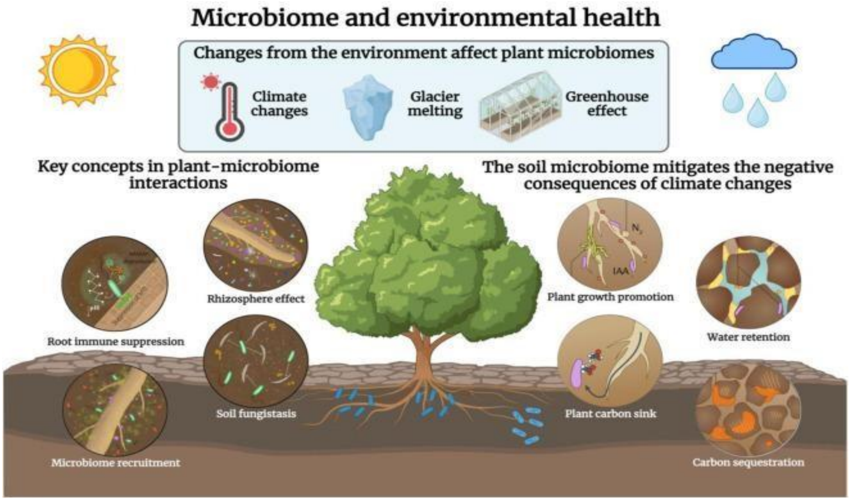
**Fungi:** Because of their tremendous plasticity and ability to take on new forms in reaction to adverse or unfavourable conditions, fungi are extremely productive soil residents. Fungi also

contribute significantly to the stability and breakdown of soil organic matter (Shah *et al*., 2021). Fungi transform dead organic materials into biomass, organic acids, and CO2. Many fungal species can act as biosorbents by accumulating harmful metals in their fruiting bodies, including lead, zinc, cadmium, copper, and mercury. Fungi are well-adapted to preserve and replace soil, hence promoting plant growth and development.

**Algae:** Algae are a diverse collection of simple, mainly autotrophic organisms that can undergo photosynthesis and capture energy from sunlight; they also serve an important role in soil as biofertilizers and soil stabilizers. Algae, like other species, can help improve soil properties like carbon content, texture, and aeration. Soil algae produce growth-promoting compounds such as hormones, vitamins, amino acids, and organic acids, which have a wide range of effects on other species. Algae have an important role in soil fertility, particularly in tropical soils, where they increase the amount of organic carbon and other organic matter in the soil, promoting soil health.

**Benefits of soil microorganisms**

Soil microorganisms have a significant impact on plant disease resistance. They can prevent pathogen invasion by increasing plant systemic disease resistance and coating root surfaces to physically protect the plant from pathogens. Soil bacteria can open up new avenues for producing sustainably grown food by improving a plant's resilience to a severe sickness. One well-known strategy for controlling pests with soil microbes is the industrial cultivation of the bacterium Bacillus thuringiensis (Bt) in the soil for caterpillars and other pests. Several Bt strains are commonly used to keep a watch on flies and beetles. Many strains of the fungus *Trichoderma* spp. have been produced as biocontrol agents for fungal plant diseases, the majority of which affect the roots. Soil bacteria can significantly contribute to nutrient enrichment in the soil, hence preserving soil production. It has been demonstrated that biological fertilization is an effective means of supplying plants with the required nutrients. Soil microorganisms support plants by turning atmospheric elemental dinitrogen ($N_2$) into ammonia and are capable of nitrogen fixation (bacteria with nitrogenase enzyme). The nitrogen fixing and nutrient mineralization activities done by soil microorganisms are vital in plant nutrition in natural environments because these reactions convert resistant forms of N, P, and S to free their components, so supplying plant nutrition.




## Conclusions

Soil contains microorganisms such as nematodes, bacteria, actinomycetes, viruses, and protozoa. They create metabolites and plant growth regulators that influence plant development and growth. Soil bacteria play an important role in recycling soil nutrients and decomposing organic waste. They increase agricultural yields, soil health, and nutrition. Plant disease tolerance is heavily controlled by soil microbes.

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# SEEDING INTELLIGENCE: THE RISE OF AI IN AGRICULTURE

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**Abstract**

Agriculture is witnessing a remarkable transformation with the integration of Artificial Intelligence (AI). This article delves into how AI is reshaping farming practices, introducing smarter ways to manage resources, protect crops, and boost productivity. From drones monitoring crop health to automated irrigation systems conserving water, AI is making farming more efficient and sustainable. It empowers farmers with data-driven insights for better decisions on planting, fertilizing, and harvesting, while also providing tools to detect pests and diseases early, ensuring healthier yields. Importantly, AI is becoming accessible to smallholder farmers, helping bridge technological gaps and fostering resilience within farming communities. With benefits like cost savings, environmental conservation, and greater adaptability to climate challenges, AI is poised to play a crucial role in securing the future of agriculture and addressing global food security needs.

**Keywords:** Artificial intelligence, Smart devices, agriculture, AI uses, IOT

The agricultural sector is undergoing a significant transformation, driven by the integration of Artificial Intelligence (AI) technologies. As the global population rises, the demand for food production escalates, creating the need for innovative solutions to improve farming efficiency and sustainability. AI plays a crucial role in this shift, reshaping traditional farming practices and introducing data-driven methods that enhance crop management, resource utilization, and overall productivity (Bannerjee *et al.,* 2018).

AI has a wide range of applications in agriculture, each with substantial impact. From precision farming techniques that optimize soil health and crop yields to predictive analytics that anticipate weather changes and pest outbreaks, AI provides farmers with the tools to make more informed decisions (Sharma *et al.,* 2021). For example, advanced algorithms analyse data from drones and sensors to monitor crop health in real-time, allowing for prompt interventions that protect yields and reduce waste. AI-

Image source: https://intellias.com/artificial-intelligence-in-agriculture/

powered systems also automate irrigation and fertilization, ensuring efficient resource use while minimizing environmental harm.

The rise of AI in agriculture not only boosts operational efficiency but also fosters sustainability. By optimizing the use of water and fertilizers, farmers can adopt eco-friendly practices that preserve soil health and reduce chemical runoff (Smith, 2018). As these technologies continue to advance, they promise to transform the agricultural landscape, helping it become more resilient to challenges such as climate change and resource scarcity.

Additionally, AI is encouraging a new era of collaboration between farmers and technology developers. Both startups and established companies are creating user-friendly platforms that make advanced agricultural technologies accessible to smallholder farmers, a benefit once limited to large-scale operations (Sharma *et al.,*2021). This democratization of technology is essential for building resilience within farming communities worldwide, ensuring that all farmers can adapt to shifting conditions and market demands.

In conclusion, the integration of AI in agriculture represents a major shift toward more intelligent farming practices. As this technology continues to mature, it has the potential to not only increase productivity but also enhance global food security, making it a vital component of modern agricultural strategies (Singh *et al.,* 2023). The path toward a more intelligent agricultural future is just beginning, offering promising possibilities for both farmers and consumers.

**Applications of AI in agriculture**

AI in agriculture has the potential to transform farming practices through precision techniques, predictive analytics, automation, and advanced livestock management. Some of the key applications include:

- **Precision Farming:** AI optimizes soil management by analyzing data from sensors, historical records, and soil samples to guide fertilization and crop rotation. Drones and satellites monitor crop health in real-time, detecting early signs of stress, disease, or pests for timely action. AI-driven irrigation systems determine optimal watering schedules based on soil moisture, weather, and crop needs, conserving water and ensuring proper hydration.
- **Predictive Analytics:** AI improves weather forecasting for better planning of planting, harvesting, and pest control. Machine learning predicts crop yields using soil quality, weather, and historical data, aiding resource allocation and market strategies. AI also analyses market trends to forecast commodity prices, helping farmers make informed decisions on crop selection, sales timing, and supply chain management.
- **Automation:** AI-powered machinery ensures precise planting and efficient land use. Robotic harvesters and drones use computer vision to identify and pick ripe produce, reducing labour costs and minimizing damage. AI drones detect pests and apply targeted treatments, cutting pesticide use and environmental impact.
- **Optimizing Automated Irrigation Systems**: AI combined with IoT sensors enables real-time decisions for precise crop irrigation, conserving water and promoting sustainability. In smart greenhouses, AI adjusts temperature, humidity, and lighting to optimize plant growth. Additionally, AI detects leaks in irrigation systems by analysing anomalies in water flow and pressure, reducing waste and preventing crop damage.

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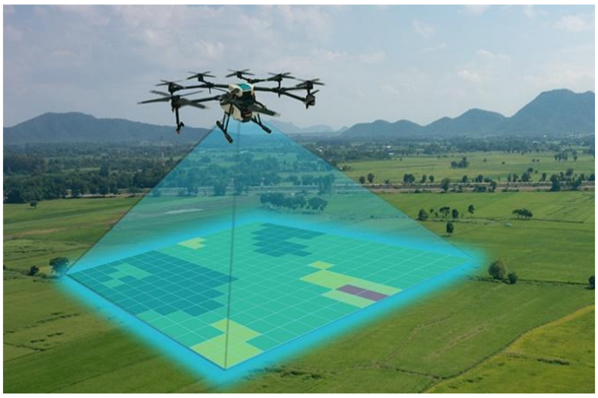
- **Crop and Soil Monitoring**: AI identifies nutrient imbalances in soil, helping farmers optimize yields. Computer vision provides accurate data on soil and crop health, enabling disease detection, yield prediction, and environmental adjustments. For example, AI has accurately tracked wheat growth stages and tomato ripeness.
- **Detecting Diseases and Pests**: AI detects pests and diseases using computer vision to scan for issues like mold and insects, enabling timely interventions. With over 90% accuracy, it identifies threats like apple black rot and various pests, preventing losses and limiting disease spread.
- **Monitoring Livestock Health**: AI uses drones, cameras, and sensors to monitor livestock, detecting abnormal behaviour and assessing diet or environmental impacts. Tools like CattleEye improve livestock well-being and boost productivity, such as milk yield.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- **Yield Mapping and Predictive Analytics**: -AI analyses drone and sensor data for precise yield predictions, aiding in planting and resource allocation. Techniques like 3D mapping and real-time data analysis optimize crop planning and returns.
- **Automatic Weeding and Harvesting**: AI-powered robots distinguish weeds from crops and automate weeding and harvesting tasks, reducing labour and improving efficiency.
- **Sorting Harvested Produce**: -AI sorts harvested crops based on size, shape, and colour while detecting pests and diseases. This speeds up grading, enhances market targeting, and reduces manual labour.

**Benefits of AI in Agriculture**

- **Cost Savings**: While AI adoption has upfront costs, it delivers long-term savings by enhancing efficiency, productivity, and resource planning. By automating tasks like crop monitoring and yield forecasting, farmers reduce labour costs and optimize planting and harvesting schedules. Real-time insights address management challenges, improving crop health and minimizing losses.
- **Data-Driven Precision**: AI enables precision farming by analyzing data on weather, soil quality, and past yields. This helps farmers make informed decisions on irrigation, fertilization, and sowing, reducing waste and boosting productivity. Automated crop monitoring and predictive analytics streamline farming processes, improving efficiency at every stage.
- **Early Pest and Disease Detection**: AI detects pests and diseases early using image recognition and real-time monitoring. Farmers can act promptly to prevent damage, ensuring healthier crops and better yields.

Image source: Researchgate

Tools like Plantix provide actionable insights, strengthening crop management and productivity.

- **Sustainability and Resilience**: AI supports sustainable farming by optimizing resource use and reducing environmental impact. It minimizes pesticide and water usage while maintaining soil health through targeted decisions based on real-time data. AI also aids in weather analysis, helping farmers adapt and maximize yields sustainably.

**Conclusion**

The integration of Artificial Intelligence (AI) in agriculture marks a transformative era for farming. With its ability to analyze vast data, automate processes, and deliver precise solutions, AI has redefined how we approach challenges like crop health, resource efficiency, and market demands. From precision farming and predictive analytics to automation and sustainable practices, AI empowers farmers to achieve higher productivity while minimizing environmental impact. Moreover, AI fosters resilience by equipping farmers with tools to adapt to climate change and resource constraints. Its accessibility to smallholder farmers ensures that technological advancements benefit all, promoting equity and inclusivity in agricultural development. As we move forward, AI's role in agriculture will only grow, offering innovative ways to enhance food security, reduce costs, and preserve natural resources. This synergy of technology and farming not only secures the future of agriculture but also strengthens its capacity to feed a growing global population sustainably and efficiently.

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# CULTIVATING CITIES: HOW URBAN AGRICULTURE ADVANCES SUSTAINABLE FOOD SYSTEMS

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**Abstract**

Urban agriculture addresses food security challenges in the face of urbanization, population growth, and environmental concerns. By producing food within cities, it enhances local food availability, reduces reliance on long-distance transportation, and fosters environmental sustainability. Methods like rooftop gardens, hydroponics, and vertical farming conserve resources, recycle waste, mitigate urban heat island effects, and improve biodiversity while reducing greenhouse gas emissions. Urban agriculture also strengthens communities, generates employment, and boosts local economies. However, challenges such as limited land, soil contamination, and climate variability limit its scalability. Sustainable practices like composting, organic farming, and native plant use can overcome these barriers. Urban agriculture thus creates resilient food systems, supporting self-sufficiency and addressing the four pillars of food security: availability, access, utilization, and stability.

## Introduction

The World Health Organization defines food security as a state where all individuals consistently have access to enough safe and nutritious food to support a healthy, active life. Traditionally, this concept is perceived as divorced from the typical urban lifestyle. In recent times, population growth and the financial crisis have made it contributory to increase the number of people in the west who cannot sustain an adequate and reliable supply of food. The increase in population and urbanization and high demands for food have led many to consider the means of food production apart from farming traditionally. This has led to the development of Urban Agriculture, defined as the production of fruit, vegetables, and herbs, and raising of animals within urban areas (Hodgson, et al. 2011).

## The necessity and current state of urban agriculture

It is now important that urban farming development be considered for improving food security in Indian cities. Bringing agriculture closer to consumers reduces reliance on long-distance transportation, which helps in reducing carbon emissions and promoting environmental sustainability. Additionally, this facilitates a healthy lifestyle, builds communal relationships, and helps individuals reconnect nature. From an economic point of view, urban agriculture benefits the local economy and offers employment. With that more than three billion people, 55% of the world's population already residing in an urban environment, which is predicted to increase to 68% by 2050, the importance of urban agriculture is gaining momentum Fig.1.

**Types of urban agriculture**

**Backyard Gardens**

Cultivating food on residential properties often leads to excess harvests, commonly shared with friends, family, and neighbours Backyard gardens benefit communities by allowing neighbors to collaborate and use diverse farming techniques, which can improve yields.

**Rooftop Gardens**

Rooftop gardening refers to the turning empty building rooftops into a green productive spot. (Tomalty and Komorowski, 2010).

**Community Gardens**

Community gardens are plots taken care of by neighbours or residents, whose produce and benefits are directly utilized by the community.

**Hydroponics**

Hydroponics is the growth of plants in water, whereby roots absorb nutrients dissolved in the water to meet growth needs. Various aggregates and media support plant growth in this soil-free method.

**Aeroponics**

Aeroponics is the growing of plants in an air or mist environment without the use of soil or aggregate media.

**Aquaponics**

Aquaponics is a self-sufficient agriculture that combines fish and plant growth within a closed-loop ecosystem. The fish production provides the waste that supplies the nutrients so essential for plant growth, while the plants contribute by purifying the water, thus creating a self-sustaining ecosystem for the fish.

**Vertical farming**

Vertical farming is an innovative agricultural method to increase food production for a growing global population. The crops are grown in vertically stacked layers or high-rise farms, saving land space and allowing for urban farming without soil.

**Living walls**

Otherwise called vertical green, vertical growing plants systems are installed on either exterior or interior of building walls.

**Major crops grown in urban farming**

Avocados, strawberries, carrots, cucumbers, green beans, salad greens, garlic greens, peas, jalapeno peppers

**Benefits of urban agriculture**

The agriculture enhances the food security and availability of nutritionally valuable food and utilizes land optimally. Besides providing an opportunity for community integration, it strengthens a resident's sense of place or a feeling of belongingness with more opportunities to learn about each other and co-operate. Local food production diminishes the heat island effect and helps in purifying the air, thus making the atmosphere healthier.

**Challenges of urban farming**

Due to some significant constraints on developing urban agriculture, many long-term viability questions have to be decided. With very scarce land available in cities and urban soils often being contaminated with metals (heavy metals) and/or pathogens, crop yield and hence food security are compromised. Farmers face difficulties in accessing inputs such as seeds and clean drinking water because the latter is often widely contaminated. Land tenure is secured by uncertain land ownership and restricted zoning regulations, and produce is difficult to both put into and distribute via extremely inadequate infrastructure. Climate change exacerbates all these challenges through increased weather variability and altered rainfall patterns. With the global population expected to rise to 8.5 billion by 2030, to address these issues has become increasingly critical.

**Food Security**

Food security is a situation when one has access to sufficient nutritious food regularly either from local production or assistance in emergency situations (Brown and Carter, 2003). It's becoming clear that traditional industrial food production methods are no longer adequate to address the global food security crisis and are not sustainable, resulting in continued depletion of the Earth's ecological resources. An estimation that urban agriculture produces between 5% and 10% of the world's legumes, vegetables, and tubers, while the combination of urban and peri-urban areas contributes about 15% to 20% of the world's total food production. According to Clinton et al. (2018) and Abdulkadir et al. (2012), the demand for food is increasing considerably. This means global food production needs to increase by about 70% by 2050, and in developing countries, it will need almost to double to meet this demand.

**Four pillars of food security**

Food access is the ability to acquire enough food, with access to food supplies and with resources and means of acquiring for production and purchase.

Food availability concerns the quantity, quality, and variety of food and is affected by factors such as production, storage, trade, and food assistance.

This process examines how the body ingests and utilizes food, considering individual taste and nutritional needs to satisfy physiological needs.

Food accessibility should be consistent, especially in periods of crisis or disruption, whereby stability enables continued access to sufficient food.

**Enhancing Food security and sustainability through urban agriculture**

Increasing local food production and making it more accessible to the community. Increasing Local Food Production and Accessibility. Food availability and community empowerment revolve around dealing with food deserts. These initiatives enhance self-sufficiency through expanded access to healthy food, build on local involvement, and culminate in better health outcomes. Decrease the food miles and, consequently, the greenhouse gas emissions from transportation. Reducing Food Miles and Transportation Emissions. The shorter supply chains help to reduce greenhouse gas emissions and enhance environmental sustainability by reducing the distance over which food has to travel. This method ensures efficient distribution and environmental sustainability in the production and consumption of food. Increased Resilience from Diversified Food Sources

Diversifying Food Sources for Increased Resilience. Locally based food systems can reduce the costs of food, improve the freshness of food, and raise its nutritional value, Fig 2.

**Urban Agriculture Ensuring sustainability**

Sustainable urban agriculture includes practices that will assure environmental and human sustainability. These could also involve the mitigation of urban heat island effect mechanisms whereby farms help in dissipating heat by absorbing oxygen, thereby cooling the surrounding environment. Mitigation of Urban Heat Island Effect: Farms help to cool the surroundings by dissipating heat and giving off oxygen through green spaces, therefore mitigating the urban heat island effect.

These farms can become habitats for local wildlife, promoting biodiversity.
Urban farming often uses locally adapted native plants, that require much less resources and maintenance as compared to other non-native plants.

Urban farming promotes healthier environments by applying organic methods, thereby greatly reducing or even eliminating the need for dangerous synthetic fertilizers, pesticides, and herbicides.

Composting in urban agriculture prevents soil erosion and boosts soil fertility by decomposing organic waste into nutrient-rich soil, thus increasing fertility and productivity.

Traditional farming techniques in water efficiency are outpaced by far with vertical farming and hydroponics, which use up to 95% less water.

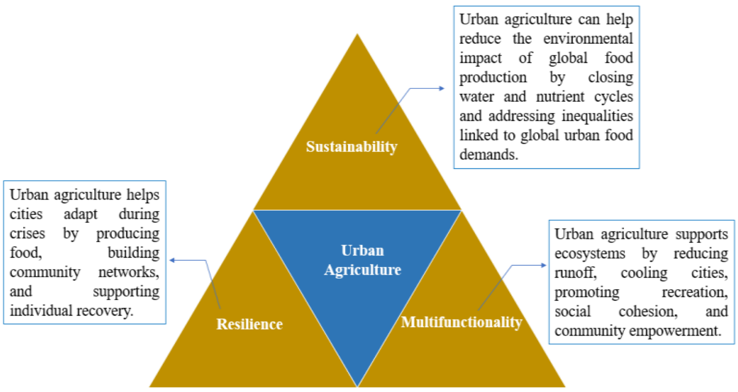


**Fig.1: Urban agriculture: a path to resilient cities and sustainable global development**

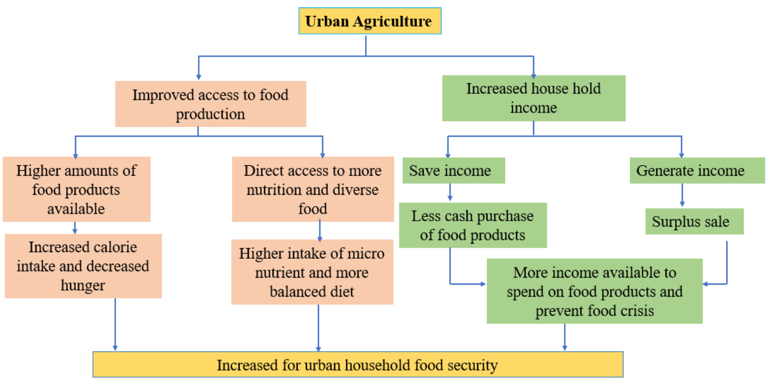


**Fig.2: Urban agriculture for household food security**

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# WATER RESOURCES: AVAILABILITY AND CONSUMPTION TRENDS IN BIHAR

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**Abstract**

Bihar is ranked 14th in terms of total water resources in the country. Besides, agriculture consumes the maximum share of 80% of the fresh water resources in the state. Only 57 percent of the gross cultivated area is under irrigation in the state. It has a total of 45793 number of water resources which is around 19% of total utilizable water resources in the country. Out of the total water resources, 95.7 percent are found in rural areas and the remaining 4.3 percent of water resources in urban areas. Among the water resources, ponds are the most common type of water resource followed by tanks and lakes. Among all the districts, Madhubani had highest number of water bodies (4893) followed by Darbhanga (3759), Banka (3344), Siwan (2978), Patna (2298) and Stamarhi (2184). The construction of water resource structures in adequate numbers and effective management are the promising approach for a sustainable water resource in the state.

**Keywords:** Urban poverty; Water resources; Agriculture; Irrigation; Sustainable water resource

## Introduction

The state Bihar is bestowed with adequate water resources of surface water and ground water. The prominent source of this water is the river Ganges facilitating year-round availability of water for domestic and agricultural purposes. The urban areas are populated with 11.3 percent of the total state's population i.e. 129.2 million but experiencing a risky life with shortage of safe drinking water (Anand *et al.*, 2022). The availability of water per capita per day is lower i.e. 50 – 135 than the recommended level by Bureau of Indian Standards (BIS) i.e. 200 liters per capita per day. Lower infrastructure of water availability deteriorates the social and economic sector of the state (Yaqoob & Musavi, 2019). Besides, water resources also play a pivotal role in Bihar agriculture. Out of the total 93.6 lakh ha area, around 60 percent of the total net cultivated area i.e. 56.03 lakh ha is under the irrigated area and 40 percent is unirrigated area. The higher the agricultural practices, the more the consumption of irrigation water. The erratic and aberrant climate conditions of the state result in insufficient availability of water in the state. Moreover, due to the increase in population, intensive agriculture and industrialization, shortage of irrigational water exists in the state (Sharma *et al.*, 2021). These water resources are crucial to conserve to meet domestic consumption and agricultural irrigation challenges. The development of water resources data based on the type, purposes etc. are essential for conservation and management to increase water use efficiency. For achieving the above objective, farmers, governmental officials and governmental policies need to join in collection of information and its conservation and management for a sustainable water resource. The adoption of water saving technologies, construction of surface water resources such as ponds, lakes, and reservoirs; and availability of infrastructures for utilizing ground water resources are the strategies for efficiency of water resources in the state.

**Significance of water resources**

Water is a fundamental natural resource for the environment, human health, industries, and agriculture. It sustains diverse ecosystems and supports the global biodiversity of plant and animal species. It plays a crucial role in regulating the climatic conditions through evaporation (Gunawardena *et al.*, 2017). Moreover, it regulates the atmospheric temperature and generates electrical energy through hydro-electric power plants for a renewable and sustainable source of energy. It is also a critical resource for agriculture from cultivation of crops to processing. Water resources include groundwater, surface water (ponds, lakes, canals), ocean water, rainwater, snow and ice. The ground water and surface water are massively used for domestic drinking and irrigation purposes. Due to misutilization and discrimination of them, they face challenges such as pollution, over-extraction, and climate change thereby threatening its availability and quality. Sustainable management and conservation practices are essential for the availability of sustainable water resources for drinking and agricultural purposes (Ahmadov, 2020). Agriculture utilizes the maximum of 80% of freshwater resources (Dhawan, 2017). However, a key challenge is the underutilization of water resources for safe domestic drinking and year-round irrigation for rainfed Indian agriculture.

**Current status of availability of water bodies in Bihar**

In India, 24,24,540 water resources are reported of which around 97% are in rural areas and rest 3% in urban areas (Ministry of Jal Shakti, 2023). The Bihar state accounts for 45,793 water bodies comprising 43,831 in rural areas and 1962 in urban areas. In Bihar, the prominent water resources include ponds, tanks, lakes, and reservoirs. Bihar holds 14th position in terms of total number of water resources and 2nd position of having lakes. Moreover, 49.8 percent of total water resources which are not utilizable due to dried up or encroachment and 70 percent of the water resources have disappeared since the last three decades. There have been adequate number of water resources in the state however gradually disappeared due to lack of concerns and managements (Chandra et al. 2023). Among the water resources, ponds are the most common type of water resource followed by tanks and lakes **(Fig. 1).** The pond water

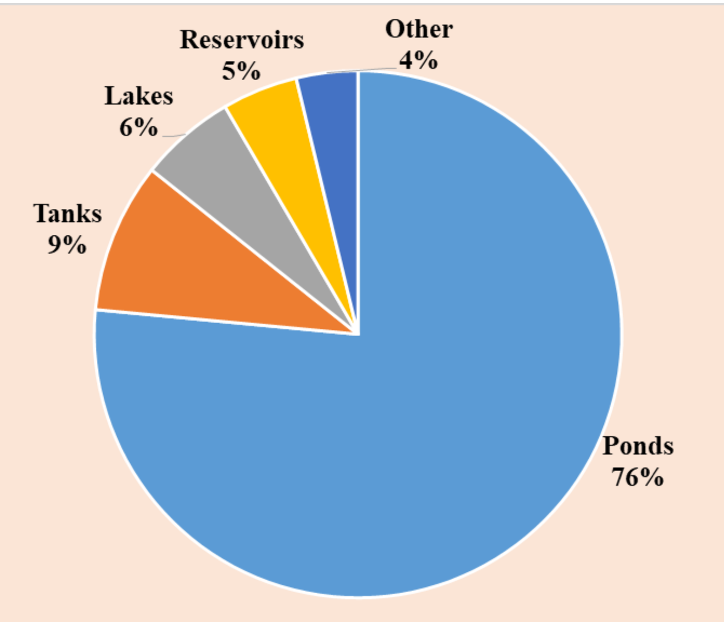


Fig 1: contribution of different water resources in Bihar

resource contributed the highest of 76.48 percent to the total water resources followed by tanks i.e. 9.21 percent and lakes i.e. 5.88 percent.

**District wise water body availability in the state**

The total area covered by water resources in each district under different Agro-Climatic zones of Bihar is presented in **Table 1**. Among the districts, Madhubani district in Zone-I holds the highest number of water resources i.e. 4893 and Begusarai had the lowest i.e. 139. Similarly, in Zone-II, the highest number of water resources exist in Araria and lowest in Khagaria while in Zone-III, the highest number of water bodies are found in Banka and the lowest in Lakhisarai. Finally in last zone-IV, Patna has maximum number of water bodies i.e. 2298 and Arwal had miimum number i.e. 49. Zone-I has the maximum number of water resources i.e. 21,264 compared with the other Zones of Bihar.

This precious water resource is required to be conserved for sustainable use. The shortage of water conservation structure in the state needs to be addressed. These structures not only help in preventing floods and soil erosion but also help in improving the availability and quality of water for various purposes.

**Table 1: Zone wise number of water resources in each district under different Agro-Climatic zones of Bihar.**

| ZONE-I | Water resources | ZONE-II | Water resources | ZONE-III | Water resource | ZONE-IV | Water resource |
|---|---|---|---|---|---|---|---|
| Saran | 1259 | Saharsa | 811 | Munger | 190 | Patna | 2298 |
| Siwan | 2978 | Supaul | 1129 | Sheikhpura | 939 | Nalanda | 1207 |
| Gopalganj | 1678 | Madhepura | 221 | Lakhisarai | 140 | Bhojpur | 1267 |
| Muzzafarpur | 785 | Purnia | 1501 | Jamui | 1046 | Buxar | 1209 |
| E.Champaran | 374 | Kishanganj | 341 | Bhagalpur | 224 | Rohtas | 1329 |
| W. Champaran | 926 | Araria | 1981 | Banka | 3344 | Kaimur | 1265 |
| Sitamarhi | 2184 | Katihar | 965 | | | Gaya | 98 |
| Sheohar | 371 | Khagaria | 178 | | | Jehanabad | 546 |
| Vaishali | 1635 | | | | | Arwal | 49 |
| Darbhanga | 3759 | | | | | Nawada | 1652 |
| Madhubani | 4893 | | | | | Aurangabad | 360 |
| Samastipur | 522 | | | | | | |
| Begusarai | 139 | | | | | | |
| **Total** | **21364** | | **7127** | | **5883** | | **11280** |

**Source:** 1st census of Report on water resources, Ministry of Jalshakti, GOI.

**Different usages of water resource**

In Bihar, ground water is the primary resource for domestic and irrigation usages. The annual utilization of groundwater for irrigation is 10.01 BCM, for domestic or drinking purposes is 3.14 BCM, and for industrial use is 0.35 BCM (CGWB, 2022). Out of the total water resources, only 50.2 percent i.e. 22,994 water resources are currently being utilized (1st census report, 2023). The remaining 49.8 percent i.e. 22,799 water resources are not utilized due to drying up, construction, salinity, and being destroyed beyond repair, and many others. The different usages of water resources are presented in **Fig 2**. Irrigation accounts for the highest usage of 45.6 percent of water resources, followed by pisciculture of 35.8 percent, and other usage of 11.7 percent. The domestic or drinking water accounts for the lowest usage of water resources i.e. 0.7 percent.

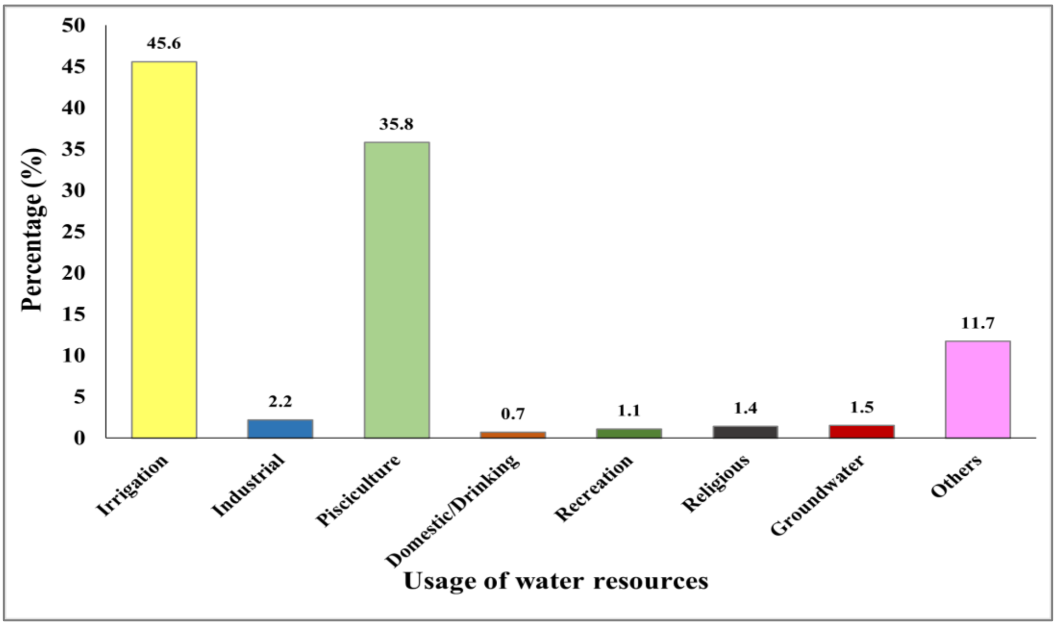


**Fig 2: Different usage of water resources in Bihar**

**Strategies for efficient use of water resources**

Bihar is facing challenges in managing water resources due to agriculture dependence, aberrant climatic conditions, and over-exploitation of water by increasing human population. Some strategies can be adopted such as rainwater harvesting, micro-irrigation (drip and sprinkler), water recycling, crop diversification, introduction of drought resistant varieties, awareness programs and infrastructure development, and individuals/community participation for efficient and sustainable use of water.

**Conclusion**

With the ever-increasing human population, the necessity of water resources either for agriculture, industries or drinking purposes is incremental. The availability of water resources is not the main concern, rather the quality of these resources is what truly matters for safe domestic and agricultural usages. Mis-utilization of water resources resulted in water pollution. The erratic and aberrant climatic condition of the Bihar state facilitates poor water resources. The conservation and management practices of water resources with the construction of dams, tanks, canals, ponds etc. for utilizing in the post-rainy season would be a promising approach. Also, agriculture practices viz. lase land levelling, use of climate resilient varieties and practices, crop diversification etc which utilizes less water should be promoted.

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# ADAPTING AGRICULTURAL STRATEGIES FOR CLIMATE RESILIENT AND SUSTAINABLE FARMING

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## Introduction

Indian agriculture is highly vulnerable to climate change, especially drought, as two-thirds of the land is rainfed and dependent on the monsoon. Floods, frost, heatwaves and cyclones further increase risks, with rising temperatures making these events more frequent, leading to significant agricultural losses. Climate change directly and indirectly impacts on crops, soils, livestock and pests. While increased carbon dioxide may boost growth in some crops, higher temperatures reduce crop duration, alter photosynthesis, and disrupt pest populations. It also affects irrigation, soil quality, and arable land, posing serious challenges to agricultural productivity and land use in India.

## Climate Resilient Agriculture

The term "climate-resilient agriculture" (CRA) refers to the blending of different agricultural practices, mitigation, and adaptation. It improves the system's capacity to endure harm and bounce back quickly from a variety of climate-related disruptions. These disturbances could include events such as floods, droughts, sharp temperature swings, erratic rainfall patterns, protracted dry spells, insect or pest outbreaks, and other possible problems brought on by climate change. CRA basically highlights the system's capacity for quick recovery. It includes the system's innate ability to recognize dangers and take appropriate action, all the while taking the effectiveness of such actions into account. The main goal of CRA is to manage natural resources - such as land, water, soil, and genetic resources - in an excellent and improved manner by implementing the best practices that are now accessible.

## Technologies for Climate Resilient Agriculture

### Climate-resilient Crop Cultivars

To maintain yield stability amid climate challenges, developing new crop cultivars with higher yield potential and resistance to multiple stresses, such as drought, flood, and salinity, is crucial. Breeding programs should focus on improving germplasm for heat tolerance and developing plants that can withstand multiple abiotic stresses. Enhancing oxidative stress tolerance and root efficiency for better water and nutrient uptake is also essential. Genetic engineering can aid in "gene pyramiding" to combine desirable traits, creating an "ideal plant type" that is climate-resilient. Traditionally, farmers relied on local crop cultivars with poor productivity due to extreme weather, but introducing enhanced, stress-resistant cultivars, supported by village-level seed production and weather-based agricultural advice, can significantly improve yields.

### Technologies for Water Conservation

Efficient use of natural resources, particularly water, is crucial for adapting to climate change as increasing temperatures and shifting precipitation patterns make water increasingly scarce. To ensure sustainable crop production and livelihoods, water conservation, harvesting, and improved irrigation efficiency are essential. Promoting on-farm water conservation techniques, micro-irrigation systems, and appropriate crop-based irrigation is playing key role. Enhancing soil-water management through practices like increasing water infiltration, reducing runoff, and minimizing soil evaporation using crop residue mulch is also vital. Additionally, water-saving technologies such as direct-seeded rice, zero-tillage, and resource conservation practices are emphasized, not only for water conservation but also for reducing greenhouse gas emissions.

**Adjusting Planting Schedule**

To reduce yield instability from high temperatures, adjusting planting dates to avoid the hottest periods is key. In arid and semi-arid tropics, where climatic variability is common, adapting the cropping calendar to align with wet periods and avoid extreme weather is crucial. Cropping systems may need to evolve to include suitable cultivars, increased cropping intensity, or diversification. Shifting from traditional puddled rice and intensively tilled wheat to alternatives like maize-wheat, pulse-wheat, maize-pulse, oilseed-wheat, and direct-seeded rice-wheat is essential. These systems use water and nutrients more efficiently, boost farmers' income, and reduce thrust on natural resources.

**Crop Insurance**

Crop insurance schemes, both private and public, are essential to help farmers mitigate the risks of crop failure due to extreme climatic events. However, effective policies are needed to encourage and facilitate these insurance opportunities. Microfinance has proven successful among the rural poor, including women, by providing low-cost access to financial services, which can greatly benefit vulnerable farmers. The expanding mobile telephony network can further enhance SMS-based banking services, improving farmers' integration with financial institutions. Developing a sustainable insurance system is crucial, and it is equally important to educate the rural poor on how to access and benefit from these financial opportunities.

**Crop Contingency Planning**

Contingency crop planning involves selecting alternative crops and cultivars suited to the specific rainfall and soil conditions of a location, particularly in rainfed areas. Early sowing with the onset of the monsoon is ideal for maximizing yields. Strategies such as resowing, thinning crops, applying nutrients like urea, $KNO_3$, or DAP, and growing storm-resistant crops like ginger and pineapple are effective practices to combat climate change. To further address climate variability, ICAR/CRIDA has developed contingency plans for over 400 rural districts across India. These plans are implemented during unusual monsoon years by district and block-level extension staff to help farmers adapt to changing climate conditions.

**Enhanced Weather-Based Agricultural Advisory**

Agromet advisories are strategies based on current and future weather conditions to protect crops from potential weather-related issues. They include assessing crop conditions, weather forecasts, identifying weather-related stresses (like drought, floods, cold, and heat waves), and providing farm management guidance. The advisories are distributed through bulletins, with responses to farmers' queries and feedback. Despite traditional knowledge, unpredictable weather challenges small and marginal farmers who lack access to modern forecasting technologies. Weather information aids in crop selection, sowing, harvesting, irrigation scheduling, and protection against adverse weather.

The Indian Council of Agricultural Research (ICAR) addresses these challenges through microlevel Agromet advisories, improving crop protection and sustaining production.

**Conclusion**

Indian agriculture faces severe challenges from climate change, including droughts, floods, and heatwaves. To address these, it’s crucial to develop climate-resilient crop varieties, optimize water use, and adjust planting schedules. Effective crop insurance and microfinance solutions are vital for managing risks and financial uncertainties. Additionally, contingency planning and enhanced weather-based advisories provide farmers with tailored strategies to cope with climate variability. Integrating these approaches will bolster agricultural resilience, productivity, and sustainability.

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# STRATEGIES TO CLIMATE CHANGE ADAPTATION AND MITIGATION BY EXTENSION SERVICES

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**Abstract**
Today, world is at the cross road in terms of facing global climatic change, so is India too. Adaptation strategies and policies are needed for managing and reducing the adverse impacts of climate change on agriculture. In the field of agriculture prime focus is on how to reduce vulnerability of farmers by enhancing their adaptability capacity towards climate change adaptation. Agricultural extension system can be the key player for initiating the step. Adaptations to climate change require changes in many domains like resilience capacities, knowledge of the field, outlook and attitude and more over skills of the people. It is expected that agricultural extension system can bring this change. Support from extension for farming community in dealing with adverse climatic conditions should focus on two major areas, first is adaptation and second is mitigation. These changes are occurring with increasing risk and decrease the adverse effects of climate change in crops. Emerging extension strategies can help farmers to deal with uncertainty and greater climate variability. It can create control measures by providing expert advice on how to tackle such climatic conditions like droughts, floods and so forth.

**Key words:** Adaptation, Climate change, Extension, Mitigation, Strategies.

## Introduction

The role of agricultural extension in the university, agriculture sector is having educational importance. Extension officials are expected to provide and disseminate valuable information to farmers. In providing institutional support and facilitating needs of farmers extension agents can serve their roles and responsibilities. In all of such models, government policy is considered very important (Van Averbeke *et al.*, 1998; Crookes, 2003). Agricultural extension has vital role to play in initiating the change.

According to FAO (2003), it has been seen that agricultural extension is involved in public information and education programs that could assist farmers in mitigating the adverse effects of climate change and such participation include awareness creation and knowledge brokerage on the issues of climate change; building resilience capacities among vulnerable individuals, communities and regions; Encouraging the broad participation of all stakeholders in addressing climate change issues and developing appropriate frameworks to prevent/ comply with climate change impacts.

According to IPCC (2011) climate change and its associated uncertainties implies that extension services need to regularly access updated knowledge and extend it in an adequate and timely manner to the farmers. It also works on harnessing the local knowledge pool i.e. scientific from extension officials and indigenous from farming community to improve adaptation practices. The low education level of some extensionist can adversely affect the quality of extension services (Mmbengwa, 2009). Yet, to comprehend and communicate climate change, extension officers need regular training to upgrade their skills and be able to advice and work together with smallholders on how to adapt to climate change. Designing policies that aim to improve role of extension services in communities have great potential to improve farmer adaptation to changes in climate. Government plans and policies need to support the training of extension officers so that they give farming communities relevant information about climate change adaptation.

**Global climate change trends and its impacts**

The impacts of climate change are being felt all over the world. It is getting warmer, rainfall is more erratic, the sea levels are rising slowly and extreme weather events are becoming more frequent and intense. Prolonged periods of drought, floods and shifting climatic zones are endangering development successes. The poor and marginalized are often most affected by climate variability and change. The Indian Ministry of Environment and Forests and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) India are working together to devise ways of dealing with the inevitable impacts of climatic change. The Climate Change Adaptation in Rural Areas of India (CCA RAI) project aims to strengthen the capacities of vulnerable rural communities in India to survive with climate variability and change. The work includes supporting governments of four partner states, local communities and other relevant stakeholders in identifying, developing and carrying out adaptation measures in pilot areas.

Mark *et al.* (2008) highlighted some of the direct impacts of climate change on agricultural system as: (a) seasonal changes in rainfall and temperature, which can affect agricultural conditions, changes in growing seasons, calendars, water availability, can remove pests, weeds and disease. Population, (b) changes in evaporation, photosynthesis and biomass production, and (c) changes in land suitability for agricultural production. Some of the induced changes are likely to end abruptly, while others include gradual changes in temperature, vegetation cover, and species distribution. Wisner *et al.* (2004) report that agricultural vulnerability is determined not by the nature and magnitude of environmental stressors, such as climate change per se, but by combining social capacity to cope with and/ or recover from environmental change. While copulation capacity and degree of risk are related to environmental changes, they are also related to both social aspects such as land use and changes in cultural practices.

**India's National Action Plan for Climate Change (NAPCC)**

In June 2008, Prime Minister Manmohan Singh released the first National Action Plan on Climate Change (NAPCC) for India. Currently, all Indian states are preparing State Action Plans on Climate Change (SAPCC) to operationalize the NAPCC. NAPCC outlines how India addresses national climate change concerns over the coming years without compromising the country's development. The plan enlists the following eight core missions addressing both climate change adaptation and mitigation concerns across different regions (GoI 2008a):

**The National Solar Mission** promotes the development and use of solar energy for electricity generation and other uses. Its ultimate objective is to make solar energy competitive with fossil-based energy options.

**The National Mission for Enhanced Energy Efficiency** aims at implementing a host of programmes that will improve energy efficiency in the energy-consuming industries and sectors. Incentives are among others: energy-savings certificates, reduced taxes for energy-efficient appliances and public private partnerships.

**The National Mission on Sustainable Habitat** promotes energy efficiency as a core component of urban planning. It includes the extension of the existing Energy Conservation Building Code as well as more efficient waste management and recycling and more environment-friendly transportation.

**The National Water Mission** sets the goal of a 20 per cent improvement in water use efficiency through pricing and other measures.

**The National Mission for Sustaining the Himalayan Ecosystem** aims to conserve biodiversity, forest cover, and other ecological values in the Himalayan region. Background: the region's glaciers, which are projected to recede as a result of global warming, are a major source of India's water supply.

**The National Mission for a 'Green India'** focuses on the afforestation of 6 million hectares of degraded forest lands and the extension of forest cover from currently 23 per cent to 33 per cent of India's territory.

**The National Mission for Sustainable Agriculture** supports climate adaptation in agriculture through the development of climate-resilient crops, the expansion of weather insurance mechanisms and innovative agricultural practices.

**The National Mission on Strategic Knowledge for Climate Change** seeks to establish a better understanding of climate science, impacts and challenges. This mission envisions a new Climate Science Research Fund, improved climate modelling, and increased international collaboration. It also encourages private sector initiatives to develop adaptation and mitigation technologies through venture capital funds.

**Meaning of adaptation to climate change**

The agricultural sector is threatened by already existing tensions, such as limited availability of water resources, land degradation, loss of biodiversity and air pollution; Thus, climate change will make already sensitive systems even more vulnerable. Climate change may improve yields of some crops from the middle to high latitudes, while crop yields will also decrease in areas such as the tropical region. Adaptation to climate change is the adjustment of human and natural systems in response to actual or expected climate stimuli or their effects that exploit moderate losses or beneficial opportunities (IPCC 2007e).

Adaptation in the agricultural sector means addressing the negative effects of climate change and utilizing the opportunities that often come with changing climate. The overall objective of adaptation in agriculture is to reduce the vulnerability of farmers and improve their adaptive capacity. A prerequisite for this is to understand climate change, especially at the level of the individual farmer, but also in a broader context. However, this includes supporting policies, a range of agricultural extension services, intensive agricultural research and innovative risk management tools. Adaptive capacity is the ability of a system to accommodate climate change (including climate variability and extremes), to moderate potential losses, to take advantage of opportunities, or to deal with consequences (IPCC 2001).

**Role of extension agencies in adaptation and mitigation**

A key element in supporting agriculture, the role of extension agencies is providing information. The cost of adopting agriculture for climate change can be large and the methods are not always well known. Mitigation efforts will require information, education and technology transfer. Thus, both public and private agricultural extension and advisory services have a major role in providing information, technology and education to farmers, knowledge of ways to contribute to climate change and greenhouse gases (GHG) mitigation. This support is particularly important for resource-less small shareholders who contribute little to climate change and will still be the most affected. Detail support for farmers in tackling climate change should focus on two areas: adaptation and mitigation (Singh and Grover, 2013).

There are several ways that extension systems can help farmers cope with climate change. These include adaptation to prevention and contingency measures that cannot be stopped. Expansion can help farmers prepare for greater climate variability and uncertainty, create contingency measures to deal with rapidly increasing risks and mitigate climate change consequences by providing advice to deal with droughts, floods and so forth. Extension can also help to mitigate climate change. This assistance may include providing links to new markets (especially carbon), new regulatory structures, and information about new government priorities and policies. It is discussed below that climate change-related adaptation and mitigation can help with extension (Singh & Grover, 2013):

**(i) Technologies and management information**

Traditionally extension has played a role in providing information and promoting new technologies or new ways of managing crops and farms. The extension also connects farmers with researchers and other actors in the innovation system. Farmers, extension agents, and researchers must work together on farmers' fields to prioritize, test, and promote new crop varieties and management techniques. While extension should now move forward in such ways, simple technology transfer is still needed to increase resilience to climate change and reduce GHS emissions. Today's farmers will need to be able to respond quickly to climate change and be able to manage risk. This would be particularly challenging to expand in terms of knowledge and information systems. Farmers need access to this kind of information, this is market through forecasting, climate information, adaptive technology innovation or expansion and information systems.

Extension agents can introduce locally appropriate techniques and management techniques, enabling farmers to adapt to climate change by developing and spreading local cultivation of drought resistant crop varieties with information on the advantages and disadvantages of crops. Additionally, extension staff can share their knowledge about crop and management systems with farmers who are resilient to changing climatic conditions such as agroforestry, intercropping, sequential cropping and agriculture. Improving some of these practices is an additional benefit of natural resource management. Plantation can also help improve soil, prevent soil erosion and increase biodiversity. It is important to provide farmers with information about how the various options will increase income and yields, protect household food security, improve soil, increase sustainability and generally help mitigate the effects of climate change. At the same time extension staff can play an important role in transferring indigenous technical knowledge to help farmers around the world. One of the main challenges for future extension is to move away from providing in-package 'technical and management advice' rather than supporting farmers with skills. They need to choose the best option to deal with climate uncertainty and variability and make informed decisions about how to engage in new markets for carbon emissions. Some farmers will also need access to new technologies and management options in areas where climate change implements their current farming systems.

**(ii) Capacity development**

One of the major activities of extension over time has been adult and non-formal education. This role continues today and is even more important in light of climate change. In addition, the extension is also responsible for providing information using technologies ranging from flyers and radio messages to field demonstrations. Recent innovative extension activities include experiential learning approaches used in adult education and farmer sector schools, an extension and education approach to working with farmers already on climate change issues. Climate Field Schools (CFS) have been established in West Java, Indonesia to deal with climate change in agriculture. Another example is a multimedia campaign planned by True Nature Kenya and the World Agroforestry Center which will feature films by extension agents and publicize educational follow-ups to promote grassroots solutions to climate change problems.

Capacity development along with extension is important. To improve outcomes in rural Development, farmers and extension agents require new skills that will require an agricultural education and extension curriculum to include assessment and understanding of the knowledge and experiences of rural people and co-education (which are farmers and extension agents who expand Farmers are learning together rather than agents those who give one way information transfer). Informing farmers about customization options and There are many different ways to educate. The Climate Change Adaptation Fund should focus on extension systems and programs that incorporate a good understanding of the activities that are needed to promote those activities in promoting activities Helps. Climate change efforts and, where needed, on enhancing the capacity of extension agents and farmers.

**(iii) Information and communication technology (ICT)**

Agricultural decisions on timely land preparation, planting, weeding, irrigation, harvesting, storage and marketing have been of central concern to agricultural stakeholders. ICTs, especially mobile telephones, can trigger the way farmers receive, exchange and manipulate information in rural areas.

**(iv) Use of technology demonstrations**

Extension agents may use various extension learning approaches including display method, result display, print media like posters, leaflets, etc. and computer/ telecommunications media (Internet, television, cinema, radio, computer, etc.) to inform and educate farmers on various issues of climate change. Farmers can adopt the technique with practice and practice learned during the demonstration session. Farmers see the use of demonstration methods as an important role of extension in the spread of coping and adaptive measures that can reduce the risk of climate change among vulnerable communities.

**(v) Training**

Poor resource farmers should be trained more, as they are less enlightened, mostly illiterate and neglected from the mainstream of development. Because their background trainings are being followed by Krishi Vigyan Kendras (KVKs), such as and by training should be based on the principles of 'training by learning' and 'learning by doing'. Most of the training for such farmers should be off-campus / village, which cannot come for residential courses; They have to take a course of one or two days. The strategy of training should be reached with special priority for boys and girls, including farmers, farm women and young farmers. We should build training infrastructure / institutes for agricultural conditions as much as possible. The promotion of KVK for each district is a good example in this regard.

## Conclusion

These climate challenges require immediate attention by the authorities concerned as the problems of climate change are already with us. Extension can play a crucial role in helping farmers to adapt and mitigate climatic changes. Today, the most important objective of extension is to be the voice of unheard farmers and they can be the game changer while taking the decision regarding mitigating and adaptive measures for climate change. Further mitigation funding can be used to capture this potential role adaptation and to support extension efforts that enhance advance technologies, information and education and increase carbon sewage and reduce Green House Gases emissions. From a very long-time extension has helped in educating farmers, promoting new agricultural technologies and management practices to facilitate rural communities.

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