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Natural Farming: A Sustainable Paradigm for Ecological Agriculture and Food Security

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Introduction

Agriculture plays a critical role in ensuring food security, supporting livelihoods, and sustaining economic development. However, conventional agricultural systems that rely heavily on chemical fertilizers, pesticides, and intensive cultivation practices have caused severe environmental degradation, including soil erosion, water contamination, and biodiversity loss (Altieri & Nicholls, 2020). These challenges have raised concerns about the long-term sustainability of modern agriculture and have prompted the search for alternative farming systems that are environmentally friendly and economically viable.

Natural farming has emerged as a sustainable agricultural paradigm that aims to restore ecological balance while maintaining crop productivity. The system is based on the principle that agriculture should work in harmony with nature rather than attempting to control it through synthetic inputs. Natural farming focuses on enhancing soil biological activity, promoting biodiversity and utilizing locally available resources to maintain soil fertility and plant health (Kumar & Singh, 2022). The concept of natural farming gained global attention through the work of Masanobu Fukuoka in Japan and has been widely promoted in India through initiatives such as Zero Budget Natural Farming (ZBNF). The approach emphasizes ecological processes such as nutrient cycling, natural pest regulation and soil microbial activity to create sustainable agricultural systems.

Principles of Natural Farming

(a) Soil as a Living System

Soil is considered the foundation of natural farming. Healthy soil contains a diverse community of microorganisms that play a vital role in nutrient cycling and plant growth. Natural farming practices

enhance soil organic matter and microbial activity, which improve soil structure, nutrient availability, and water retention capacity (Saharan *et al.*, 2023). Maintaining soil health is therefore essential for sustainable crop production and ecosystem stability.



(b) Minimal External Inputs

One of the key principles of natural farming is reducing dependence on external inputs such as chemical fertilizers and pesticides. Instead, farmers rely on locally available resources such as farmyard manure, crop residues, cow dung, and plant extracts. This approach reduces production costs and minimizes environmental pollution while maintaining soil fertility (Yadav & Singh, 2024).

(c) Biodiversity and Crop Diversification

Natural farming encourages crop diversification through intercropping, mixed cropping, and crop rotation. Diverse cropping systems improve ecosystem resilience and reduce pest and disease outbreaks. Biodiversity also enhances nutrient cycling and supports beneficial insects that contribute to natural pest control (Pretty *et al.*, 2021).

(d) Soil Cover and Mulching

Mulching is an important practice in natural farming that involves covering the soil surface with organic materials such as straw, leaves or crop residues. Mulching helps conserve soil moisture, suppress weeds, regulate soil temperature, and increase soil organic matter content. These benefits improve soil fertility and crop productivity (Maurya *et al.*, 2023).



Key Practices in Natural Farming

(a) Jivamrita

Jivamrita is a microbial formulation prepared using cow dung, cow urine, jaggery, pulse flour, and soil. It acts as a biofertilizer that enhances microbial activity in the soil and improves nutrient availability for plants. Regular application of Jivamrita supports soil biological processes and promotes healthy plant growth (Kumar & Singh, 2022).

(b) Bijamrita

Bijamrita is used for seed treatment in natural farming systems. It is prepared using cow dung, cow urine, lime, and soil. The treatment protects seeds from fungal and bacterial infections and improves seed germination and seedling vigor.



(c) Mulching

Organic mulching is widely practiced in natural farming to maintain soil moisture and improve soil fertility. Mulching also provides a suitable environment for beneficial soil organisms and helps reduce soil erosion.

(d) Crop Diversification

Crop diversification through intercropping and mixed cropping enhances biodiversity and reduces pest incidence. It also improves



soil nutrient balance and increases farm resilience against climate variability.

Ecological Benefits of Natural Farming

(a) Improved Soil Health

Natural farming practices significantly improve soil organic matter content and microbial diversity. Healthy soils enhance nutrient cycling, water retention, and root development, which ultimately improve crop productivity (Saharan *et al.*, 2023).

(b) Biodiversity Conservation

Natural farming supports biodiversity by avoiding chemical inputs and encouraging diverse cropping systems. Beneficial insects, pollinators, and soil organisms thrive in such environments, contributing to ecosystem stability (Altieri & Nicholls, 2020).

(c) Reduced Environmental Pollution

The elimination of synthetic fertilizers and pesticides reduces soil and water contamination. Natural farming therefore contributes to environmental conservation and protects ecosystem health.

(d) Climate Change Mitigation

Natural farming practices enhance soil carbon sequestration and reduce greenhouse gas emissions associated with chemical fertilizer production and use. This contributes to climate change mitigation and promotes climate-resilient agriculture.

Natural Farming and Food Security

Food security depends on the availability, accessibility and sustainability of food production systems. Natural farming contributes to food security by improving soil fertility, reducing production costs and enhancing agricultural sustainability. Healthy soils with high organic matter support stable crop yields even under adverse environmental conditions (Bharucha & Pretty, 2020).

Natural farming also promotes diversified cropping systems that improve nutritional security by providing a variety of food

crops. Additionally, chemical-free food produced through natural farming improves food quality and reduces health risks associated with pesticide residues. These benefits make natural farming an important strategy for achieving sustainable food systems and ensuring long-term food security.

Challenges and Limitations

Despite its numerous benefits, natural farming faces several challenges that hinder its widespread adoption. One of the major challenges is the potential decline in crop yields during the initial transition period from conventional farming systems. Farmers may require time to restore soil biological activity and ecological balance before achieving stable yields (Sharma *et al.*, 2025).

Another challenge is the lack of awareness and technical knowledge among farmers regarding natural farming practices. Effective training programs and extension services are therefore necessary to promote adoption. Additionally, limited market opportunities for natural farming products and inadequate policy support may discourage farmers from adopting these practices.

Future Prospects

Natural farming has the potential to transform modern agriculture into a more sustainable and environmentally friendly system. Integrating natural farming with scientific innovations such as soil microbiology, climate-smart agriculture and precision farming can improve its effectiveness and scalability. Government policies that support ecological farming, farmer training programs and market incentives can accelerate the adoption of natural farming practices.

Conclusion

Natural farming represents a promising approach to achieving sustainable



agriculture and long-term food security. By emphasizing ecological balance, soil health, biodiversity conservation and minimal external inputs, natural farming offers an environmentally friendly alternative to conventional agriculture. The system improves soil fertility, reduces production costs, and contributes to climate change mitigation while supporting sustainable food systems. Although challenges such as yield variability and limited awareness remain, continued research, policy support and farmer education can enhance the adoption of natural farming practices. As global concerns about environmental degradation and food insecurity continue to grow, natural farming provides a viable pathway toward resilient and sustainable agricultural systems.

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Doubling Farmers Income through Smart High- Tech Farming

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Introduction

The Indian economy is based on agriculture. It serves as the primary source of income for more than 55 per cent of the total population. India occupies first position in production of various agricultural commodities such as sugarcane, sugar, jute etc. Our country ranks second in the world for rice, fruit and vegetable production. All this became possible due to the constant efforts of government, public as well as private sector and most importantly farmers, in research and development of horticulture. But, at the same time the average productivity of Indian farms is low i.e. 33 per cent of the best farms all over the world. There is need to augment this productivity so that the farmers can harness better income from the same piece of land with less input of resources. This can be achieved through implementation of improved agricultural practices. Precision farming is one such technique which aims at boosting farmer income by precise application of inputs. The developed countries are already following precision farming technology. But for developing countries, it is a newer concept that is slowly gaining a strong foothold.

Precision farming

The precision farming is about doing right thing, in right place, in right way and at right time. The adoption of precision farming techniques allows efficient use of information, technology and management which thereby increases the productivity, improve the product quality, conserves energy and protects environment.

Advantages of Precision Farming

1. It focuses on crop specific requirements.
2. Improves time management efficiency.
3. Promotes eco-friendly crop practices.
4. Reduces input cost and augments production leading to better income generation.

Key Factors for Precision Farming

1. Precise Information

The use of precision farming techniques

is based on generation and documentation of necessary information about the various aspects of soil (soil type, soil moisture content, nutrient status etc.), crop (yield, intensity of insect pest infestation, nutrient status) and climate (temperature, relative humidity, pan evaporation, wind velocity, rainfall etc.).

2. Precise Technology

- Geographic Information System
- Geographic Positioning System
- Remote Sensing

3. Proper Management

The efficient management of input resources, data and technology to harness better yield and quality.

Ways of Precision Farming

1. Irrigation and Water management:



The adoption of précised water management practices in agriculture can aid in improving water use efficiency. Micro-irrigation is one such technique. It allows slow and regular application of water directly to the root zone of plants through a network of pipes and low discharge

emitters. The application of water through this network of pipes (micro-irrigation technology) warrants 40-70 per cent water-saving and 30 per cent fertilizer-saving (Table 1). The common micro-irrigation technologies include drip irrigation system, sprinkler and bubbler.

Table 1: Water saving and yield increase in different crops under Micro-irrigation

S.No.	Crop	Water Saving (%)	Yield Increase (%)
1.	Apple	50-55	20
2.	Brinjal	55-80	17-25
3.	Bottle Gourd	12	47
4.	Cabbage	59.5	23-40
4.	Guava	55-60	25
5.	Grapes	65-70	30
6.	Lady Finger	49-84	7-13
7.	Sugarcane	30-60	20-29

2. Nutrient management

Besides being laborious and time consuming, the conventional methods of fertilizer application such as broadcasting also promote excessive loss of fertilizers due to leaching. Therefore the précised application of fertilizers is equally important for better

nutrient use efficiency and higher yields. This can be accomplished by fertigation which deals with the simultaneous injection of fertilizers in the irrigation system by means of ventury injector, fertilizer tank or fertilizer injection pump.

Table 2: Fertigation scheduling in different crops

Crop	Recommended Fertilizer dose (N:P:K)	Fertilizer scheduling
Paddy	120:60:40 kg/h	Fertigation of water soluble fertilizers at 7days interval. 30%N, 60%P and 40%K applied as basal dose and remaining through fertigation applied at weekly interval.
Potato	214.5:67.5:434 kg/h	
Tomato	120:60:50 kg/h	30% N, 60 % P and 40% K applied as basal dose and remaining via weekly fertigation.
Mango	1000:500:1000g/plant	25% of full dose during Oct and remaining dose in two splits during Feb and June
Guava	350:240:200 g/plant	--

3. Quality Planting material/Nursery

A good quality planting material/nursery serves as the basis for higher yields which can be attained by adoption of efficient plant propagation techniques and development of well manageable nursery. Plastics are commercially used in raising nurseries.

The different forms of plastics like nursery bags, pro-trays, plastic plugs etc. can be employed in nursery for better plant propagation. Plant propagation through air-layering, budding and grafting also utilizes polyethylene (150 gauge thickness) which ensures moisture conservation and at the



same time checks the entry of rain water in gootee or bud/graft joint.

4. Protected Cultivation

Farmers are facing serious setbacks due to the sudden climatic aberrations and weather extremes. The heavy losses incurred by farmers on account of climate changes can be managed by virtue of protected cultivation technology. Protected cultivation technology creates partially modified environmental conditions which allows round the year seasonal and off-seasonal cultivation of vegetables, fruits (strawberry, papaya) and ornamental crops. A wide variety of protected structures (viz., polyhouse, shade net, insect net, poly tunnels, walk-in-tunnels etc.) are commercially available which can be installed by farmers as per their needs. Round the year production of various crops like tomato, capsicum,

cucumber can be obtained under polyhouse (Table 2). Naturally ventilated low cost poly-houses are also utilized in raising quality nursery. Shade nets are widely used for hardening of tissue culture plants, nursery raising of fruits and vegetables and production of flower and other ornamental plants. These are designed using 100 per cent polyethylene thread with specialised UV treatment and are available in different shade percentage or shade factor such as 15 per cent, 35 per cent, 40 per cent, 50 per cent, 75 per cent and 90 per cent and colours like white, black, red, blue, yellow and green and in combinations. Poly tunnels often are combined with plastic mulch. The resulting combined “double layer” of film cover allows early maturity along with wind and frost protection. They also offer a temperature gain of 2-3°C.

Table 3: Off-season Vegetable production under low-cost polyhouse (100m²)

Crop	Variety	Spacing (cm)	Crop duration (months)	Total production (kg/100 m ²)	Estimated Sale Price (Rs./kg)	Cost of cultivation (Rs.)	Total income (Rs.)	Net Profit (Rs.)
Bitter Gourd	Gynoecious	60 × 50	4	350	30	6,000	10,500	4,500
Cucumber	Parthenocarpic	50 × 50	4	325	30	6,000	9,750	3,750
Cherry Tomato	Cherry Red	60 × 50	5	350	75	7,000	26,250	19,500
Gherkin	DG-6	50 × 50	4	270	50	7,000	13,500	6,500

5. Surface cover cultivation

Mulching is a technique of covering ground surface (tree basins and inter spaces between plants) with crop residues like straw, leaves, saw dust, pine needles and other materials like polythene films. Organic mulches improve soil properties but encourage the risk of fire hazards. On the other hand, plastic mulches are relatively safe. These are cost effective, easy to use, and economical. The use of plastic

mulch in combination with micro-irrigation technology offers several benefits such as efficient weed control, reduced soil erosion, soil moisture conservation, reduced loss of soil nutrients via leaching and desirable soil temperature which may lead to enhanced crop yields and improved quality thereby better income to farmers.

Soil solarisation is another aspect of surface cover cultivation. It is carried in summer months (April-May) by covering the moist



soil with a 25 micron transparent polyethylene film for controlling weeds, bacteria, fungi, nematodes and other soil borne pathogens and pests.

Table 4: Technical specification of Plastics Mulch

Thickness in films			Coverage area per kg of film (sq. m.)	Type of crops
Microns	Gauge	mm		
7	28	0.007	153-200	Short duration crops (3-4 months)
10	40	0.01	100-107	
25	100	0.025	43-48	
50	200	0.05	21	Medium duration crops (up to 1 year)
100	400	0.1	11	Long duration crops (more than one year)

6. High Density Planting

Another important technique for profitable cropping is high density planting system which deals with dense planting of trees

resulting into higher yields per unit area. This can be achieved by use of genetically dwarf varieties and rootstocks, appropriate pruning techniques and growth regulating chemicals.

Table 5: Comparative performance of mango under different planting systems

Crop	Variety	Plant Spacing	Number of trees	Yield
Mango	Dashehari	10 m × 10 m	100	7-8 t/h
		5 m × 5 m	400	14-15 t/h
		2.5 m × 3 m	1333	26 t/h

Conclusion

The precision farming relies on site-specific management. The adoption of such techniques can provide a boost in the Indian economy by reducing the cost of input with the simultaneous increase in output

resulting into better farm incomes. A full-fledged knowledge about the crop, soil and climate on part of farmers along with the proper utilization of the same for efficient management can thus play a vital role in doubling the Indian farmer's income.





Scaling Up Microbial Based Improved Technology for Grey Water Treatment

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Introduction

Freshwater on Earth is significantly more abundant than what humans need. Ninety-seven percent of Earth's total water resources are contained in the oceans, with the remaining three percent available for direct use. Of this three percent, just one hundredth is thought to be available for human use [6; 7]. Acute water shortages, excessive resource exploitation that slowly depletes water supplies, and high levels of freshwater pollution brought on by human activity plague many regions of the world. Around 800 million people are thought to be living in water stress at the moment, and by 2025, that figure is predicted to rise to 3 billion [8]. Wastewater that does not contain any toilet water is referred to as greywater [4; 12; 15]. It is thought to be low-strength, high-volume wastewater with a lot of application and reuse potential. Greywater's composition varies and is influenced by fixtures, climate, and way of life [1,5; 9]. Greywater reuse is not a new concept; it has long been practiced in water-stressed countries. Greywater that has been recycled can be utilized for a variety of water-demanding tasks, such as agriculture and both potable and non-potable purposes like flushing toilets. Public health views and unsuitable technology for the reuse option have been the main causes of concern when it comes to greywater reuse [16]. Greywater features in relation to fixtures, lifestyle patterns, and settlement types have been the subject of much research [3; 5; 12]. Reusing treated wastewater, treatment plant performance Wastewater needs to be closely inspected. Environmental standards should be met by the amount of effluent physical parameters (temperature, pH, conductivity, turbidity, colour, odour, and dissolved oxygen) and chemical parameters (COD, BOD5, TSS, heavy metals, nitrogen, phosphate, chloride, alkalinity, CaCO₃, ammonia, oxygen, and biological parameters determined with bioassays aquatic toxicology test). The use of treated wastewater for irrigation and agriculture, as well as the circumstances of discharge to surface water and release to absorbent wells, are all taken into consideration by the environmental requirements. It is crucial to understand the rules, norms, and tariffs pertaining to the treatment of sludge and wastewater for reuse or disposal [10,14]

Materials and Methodology

Study area. The Gray water treatment plant in Shikarpur, Jalpaiguri, West Bengal,

India

Procedure of Graywater Treatment Technology. In the first step, the waste water



may be introduced in the waste water treatment plant through the drainage system. In second step, the water is passed through the grit screening chamber, where the settleable solid settles at the bottom of the chamber and large particles are screened in the process.

The screen particles may be then collected

into the treatment bed where the microbial solution is used. The system is based on the specific plants, such as Elephant grass (*Pennisetumpurpurem*), Cattails (*Typha sp.*), Reeds (*Phragmites sp.*), *Cannas pp.* and Yellow flag iris (*Iris pseudocorus*), normally found in natural wetlands with filtration and treatment capability.

Results and Discussion

Table 1- Physical and Chemical Parameters

Physical and chemical parameters	Control Value	Analysis Value after treatment
pH	8.2	7.1
Colour	Cloudy grey	Transparent fluid
Turbidity	500 NTU	43.3 NTU
Total suspended solids	40 mg/lit	5 mg/lit
Total dissolved solids	2500 mg/lit	450 mg/lit
Biological Oxygen Demand(BOD)	63 mgO ² /lit	10 mgO ² /lit
Nitrate	10 mg/lit	5 mg/lit
Sulphate	309 mg lit-1	103 mg lit-1
Phosphate	4-15 mgP mg/lit	0.7 mgP mg/lit
Chemical Oxygen Demand(COD)	1000 mgO ² /lit	60 mgO ² /lit
Ammonium	850.94 mgN/lit	15 mgN/lit
Heavy metals		
Cu	5.216 mg/lit	0.21-0.5 mg/lit
Pb	3.224 mg/lit	0.06-0.09 mg/lit
Zn	4.332 mg/lit	0.1-0.16mg/lit
Co	2.206 mg/lit	0.002-0.01mg/lit

Table 2- Microbial Tests Microbial Tests

Biological Tets	Control value	Analysis value after treatment
Total coliforms MPN/100ml	1000	50
Faecal coliforms MPN/100ml	1000	69.7

Table 3: Standards and guidelines for reuse of treated wastewater. [12]

Water quality physical, chemical and biological parameter	Units	KSA Standards for Restricted irrigation S1- Existing Situation	KSA Standards for Unrestricted irrigation S2- Existing situation
Total dissolved solids(TDS)	mg/L	2500	2000
Total suspended soilds (TSS)	mg/L	40	10
pH	--	6-8.4	6-8.4



Water quality physical, chemical and biological parameter	Units	KSA Standards for Restricted irrigation S1- Existing Situation	KSA Standards for Unrestricted irrigation S2- Existing situation
BOD	mg/L	40	10
COD	mg/L	50	50
Ammonia	mg/L	5	5
Nitrate	mg/L	10	10
Phosphate	mg/L	10	10i
Total coliforms	MPN/100mL	1000	10
Fecal coliforms	MPN/100mL	1000	2.2

Table-4: Comparison of Iranian standard for various uses of wastewater treated through the system. [11]

Parameters	Wastewater treated through the system	Iranian environmental standard for Agricultural and irrigation (permissible limits and system status)	Iranian environmental standard for absorbent well (permissible limits and system status)	Iranian environmental standard or discharging in surface water (permissible limits and system status)
pH	7.1	6.5-8.5 (System status Pass)	5-9 (System status pass)	6-8.5 (System status- Pass)
TSS (mg/L)	5	40 (System status- pass)	- (System status- Fail)	100 (System status- Pass)
BOD (mg/L)	10	30 (System status- pass)	30 (System status- Pass)	100 (System Status- Pass)
COD (mg/L)	60	60 (System status- Pass)	60 (System Status- pass)	200 (System Status- Pass)
Total coliform (MPN/100 mL)	50	1000 (System status- Pass)	1000 (System Status- Pass)	1000 (System Status- Pass)

The average results of the analysis of the physical and chemical characteristics of grey water is illustrated in table 1. The most significant pollutants and parameters in the waste water of the constructed wetland by wastewater treatment technology, which plays a decisive role in the selection of the treatment system and the design criteria of

units have been investigated in this study. We compare our experimental value of the parameters with two standard values (KSA standard value and Iranian environmental standard for agricultural irrigation, absorbent well and discharging in surface water). The pH of waste water is alkaline which is not favourable for the biological



process. Here after treatment the pH comes to 7.1 which is suitable for the environment and for the plant also. pH also effects the alkalinity, colour and turbidity of wastewater. When pH comes down to 7.1 the alkalinity also comes down to neutral, turbidity from 500 NTU to 43.3 NTU and the colour from cloudy grey to transparent. TSS from 40 mg/lit to 5 mg/lit, which is a little more than the permissible limit of discharging for absorbent well but fit for surface water, irrigation of agricultural land and TDS from 2500 mg/Lit to 450 mg/lit which is perfectly fit for agricultural irrigation. The measured COD value before the treatment was 1000 mgO²/lit and after the treatment which is closed to 60 mgO²/lit which is within the permissible limit for absorbent well and surface water and it is almost suitable for industrial and domestic construction work and also suitable for irrigation of agriculture land and green spaces. The amount of BOD measured before the treatment was 63 mgO²/lit, which after the treatment comes down to 10 mgO²/lit,. According to the result obtain from table 1 and it can be concluded that all the values of heavy metals [Zn, Co, Pb, Cu] NO₃, PO₃⁻ and turbidity were determined. In the treated water they are within the permissible standard range. From the heavy metal report it can be carried out that all the studied heavy metals in the effluent are within allowed range. Therefore the effluent water can be used as industrial and domestic construction work, agricultural irrigation and green spaces. The average concentration of metal in treated wastewater is Co<Pb<Zn<Cu. So, in this study the amount of heavy metals found within the limits. The microbial study of faecal sludge waste water showed that it can be a source of coliform bacteria that are generally present in the environment and in the greywater of all warm blooded animals and humans. Coliform bacteria will not likely

cause illness. However, there presence in drinking water indicates that disease causing organisms (pathogens) could be in the water system. In this study it has been shown that the number of coliform bacteria comes down after the treatment. According to the results obtained from the treated sludge and waste water, it is possible to realise the high efficiency of the wastewater treatment plant in lab based pilot project in Raiganj, Uttar Dinajpur, West Bengal, India. We can conclude comparing the results of the obtained data of the output treated effluent with the standards of the Iranian Environmental Protection Organization shows that it is within the permissible limit for discharging to surface water, agricultural irrigation.

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Chow-Chow: An Underappreciated Vegetable with Significant Nutritional and Medicinal Value

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Introduction

Chow-chow (*Sechium edule*), an underutilized cucurbitaceous vegetable, native to Central America and humid tropical region of Mexico, is monoecious, perennial vine with tuberous roots. Its vine produces a large number of fruits that are single seeded and viviparous. Chow Chow also known as Chayote in (Hindi), Isqush (Nepali), Piskut (Khasi) and Sikut (Garo) in North-Eastern Hill regions is a member of cucurbitaceous family. In India, chow-chow is widely grown in Madurai and Nilgiri district of Tamil Nadu, Karnataka, West Bengal, Mandi district of Himachal Pradesh and the entire North Eastern Hill (NEH) region. In the NEH region, chow-chow is grown in kitchen gardens of every tribe, as an important component of their daily diet. Fruits of this crop are mainly used as vegetables and it is also used for making sweets and sauce. Though it is a native of Mexico, but considerable diversity is found in NEH region particularly, Meghalaya, Mizoram, and Sikkim. Mizoram is the leading state with an estimated area of 845 ha and 10985 MT production. It is mainly propagated by means of seed (whole fruit with seed)/ sprouted fruits, these days, it is cultivated in tropical and subtropical regions all over the world. Fruits, fragile shoots, young leaves, and tuberous roots are the plant's edible components. Although chow-chow is a fruit, it is typically consumed as a vegetable. It is frequently substituted for potatoes. The fruits of Chow-Chow are pear-shaped and brilliant green. Chayote has numerous nutritional and therapeutic advantages.

Nutritional value

Chow-chow vegetables are a vital part of a healthy diet for people. Additionally, because of its great nutritional value, abundance of vital minerals, fiber, antioxidants, and vitamin C, it is one of the primary forces behind achieving global nutritional security. Additionally, fiber is a crucial component for maintaining good health and a healthy digestive tract. In

addition to being low in calories, this soft vegetable with deep ridges provides a lot of potassium, magnesium, manganese, copper, K, B6, B9 or folate. Several essential amino acids, including aspartic acid, glutamic acid, alanine, arginine, cysteine, phenylalanine, glycine, histidine, isoleucine, leucine, methionine, proline, serine, tyrosine, threonine, and valine, are abundant in the fruits and seeds, which also have higher



antioxidant activity. The softer consistency to pastes, sauces, baby food, and liquids. Additionally, chow chow has pharmacological and phytochemical qualities. According to certain studies, chow-chow contains polyphenols such as tannins, stilbenes, and phenolic acids. The body and health are known to benefit from polyphenols' anti-allergic, anti-inflammatory, antiviral, anti-carcinogenic and hypoglycemic properties.



Composition

1. Energy: 15 kcal
2. Carbohydrates: 3.6g
3. Fiber: 1.2g
4. Protein: 0.6g
5. Fat: 0.1g
6. Vitamin C: 10% of the Daily Value (DV)
7. Vitamin K: 25% of the DV
8. Potassium: 5% of the DV
9. Magnesium: 3% of the DV
10. Phosphorus: 2% of the DV

Health benefits of Chow-chow-

1. Uses of chayote for Protects Heart

Rich in phytochemicals, Chayote plays a major role in improving blood flow, thus regulating high blood pressure. The presence of myricetin, an antioxidant not only brings down the levels of cholesterol but also fights against inflammation, thus preventing chronic cardiovascular diseases.

Add this vegetable to your daily diet for protecting the health of your most vital organ, the heart.

2. Improves Liver Function

A fatty liver is a dangerous condition, and it can happen in non-alcoholics as well. Various studies signal that regular intake of this nutritious vegetable considerably brings down the fatty deposits in liver and also reduces the levels of bad cholesterol of LDL.

3. Regulates Blood Sugar

Low on carbs and loaded with dietary fibre, Chayote should be the part of a diabetic's diet plan. Chayote not only makes you feel satiated for longer hours, but presence of fibre prevents the faster absorption of carbohydrates thus regulating blood sugar levels. Studies reveal that the presence of certain chemical compounds in Chayote improves insulin sensitivity, aids in better control of blood sugar levels in those suffering from type 2 diabetes.

4. Supports Healthy Pregnancy

Folate is a primary nutrient any pregnant woman would require in ample amounts for delivering a healthy baby. Also referred as Vitamin B9, folate is in fact recommended to every woman trying to get pregnant as it plays a crucial role in the healthy development of fetal brain, spinal cord and proper growth of the baby. Chayote Squash comes with a whopping amount of 40% of daily recommended intake of folate for a pregnant woman. All you need is one Chayote daily to meet most of your folate requirements.

5. Rich in Antioxidants

Chayote Squash is loaded with a wide range of antioxidants including quercetin, myricetin, kaempferol, morin which fight against various chronic conditions including diabetes, cancer, and inflammation. Thanks to the impressive presence of Vitamin C, this super vegetable is a must-



have for fighting various bacterial and viral infections that are quite common in rainy and winter seasons.

6. Prevents Cancer

Chayote, being rich in antioxidants fights against free radicals thus slowing down the progression of cancer cells, especially in those suffering from leukaemia and cervical cancer. The presence of flavonoids in Chayote, not only have anti-cancer activity but restrict the growth of cancer cells and prevent metastasis. These compounds reportedly eliminate oxidant which are responsible for the faster growth of tumours and for these reasons, it is strongly recommended into the diet chart of the cancer patients.

7. Slows Down Aging

This super vegetable can effectively reduce oxidative stress, which may have a negative impact on the body cells, thus making skin look dull and pale. Eating Chayote brings down the signs of metabolic syndrome, thus protecting the body from cell damage.

8. Good for the Gut

A great digestive function means a healthy you and it is responsible for optimum absorption of nutrients. Eating Chayote boosts digestive health, ensures regular detoxification. An ample presence of flavonoids, plant compounds in Chayote prevent constipation, regulate bowel movement, maintain the growth of healthy gut bacteria thus optimizing various functions of digestive tract.

9. Aids in Weight Loss

Chayote is your must-have vegetable if you are on a strict diet regimen, hoping to shed those extra kilos. Quite low on calories, it is extremely beneficial for weight watchers and those practicing calorie deficit diet plans. Being rich in dietary fibre it helps in resisting mid-day hunger pangs and in suppressing appetite.

10. Triggers Cognitive Function

Being rich in antioxidants, flavonoids and

other plant compounds Chayote is extremely beneficial in those suffering from cognitive decline. Various studies prove that this vegetable is very effective in bringing down the durations between the episodes of convulsions, improves mood disorders, and prevents depression. It is also widely recommended for improving motor coordination in those suffering from Parkinson's disease and Alzheimer's.

Conclusion

Chayote or chow chow contains high levels of various health-enhancing substances with potential applications in food, cosmetic and pharmaceutical industries. However, limited attention has been given to underutilized or neglected crops, chayote by-products are an excellent source of bioactive compounds and its use could become an important aspect in waste management from both economic and environmental standpoints.

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Lemon Grass

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Introduction

Lemon grass commonly known as “East Indian Lemon grass” is a perennial and multicut aromatic grass. The typical lemon-like odour, which is mainly due to the presence of citral, a cyclic monoterpene. Lemon grass (*Cymbopogon flexuosus*), belonging to family Poaceae, is the source of lemon grass oil obtained from the leaves and shoots of the plant. Lemon grass oil is mainly used in the manufacture of perfumes for soaps, hair oils, scents and medicines. It also has antibacterial properties. Ionone prepared from the citral present in lemongrass oil was one of the most important raw materials for the preparation of Vitamin A. In addition to its use in perfumery, Ionone is used in certain kinds of confectionary and liquors. The oil can be used to improve the flavor of some fish and can be used to flavor wines and sauces. It can be used for headache, tooth aches, baths, and as a diuretic agent for fever. Lemon grass oil is used as a main substitute for ‘Cod liver oil’.

Area and production

Traditionally, India has been the largest supplier of lemon grass oil to the world market but has ceased to be so any longer. The crop is under cultivation in India in an area of about 2000ha. The production of oil which was 1800t in 1961-62 has declined to about 400t at present. The Indian monopoly in the lemon grass trade in the world market has been broken due to the entry of Guatemala and a few other Latin American states including Brazil and Mexico, Puerto Rico, Dominica, and China.

Varieties

Sugandhi (OD-19), Pragathi, Praman, RRL- 16, CKP- 25

Types of Lemon grass

There are three types of lemon grass namely

The East Indian or true lemon grass (*C. flexuosus*)

The West Indian lemon grass (*C. citratus*)

The North Indian type (*C. pendulus*)

Soil & Climate

It flourishes in a wide variety of soils ranging from rich loam to poor laterite; best suited to well drained sandy loam. Waterlogged conditions should be avoided as they are unsuitable for its cultivation.

It requires a warm humid climate with plenty of sunshine and rainfall ranging from 1800 to 3000 mm. High temperature and sunshine are conducive to the development of oil in the plant.

Propagation

Lemon grass is generally propagated through seeds, vegetative propagation and rooted slips. It is reported that both the seedlings and rooted slips performed equally well, with respect to growth and yield. But due to high cost of transplanting, direct seeding is widely practiced, especially



over the plains and the terraced lands in Kerala. For raising the crop by direct seeding a seed rate of 20 to 25 kg/ha is recommended. While sowing, the seeds must be thoroughly mixed with dry river sand in a ratio of 1:3, to ensure the uniform distribution of seeds during storage.

Nursery raising

The seeds collected during the month of January – February are usually sown in the nursery during April – May.

Transplanting

The land is prepared by repeated ploughing and harrowing, and beds of 1 to 1.5 m width and convenient length are made with a spacing of 30 to 50 cm between beds. The beds are made along the contour of the land slopes. Three to four leaves, 50 to 70 days old seedlings are planted during the monsoon season (May- June) in Kerala. A spacing of 30cm x 30cm with a plant density of 1,11,000/ha is recommended. A wider spacing of 60cm x 45cm for seedlings and 90 cm x 60 cm for slips has been recommended for fertile, irrigated land under North Indian conditions.

Manures and fertilizer application

FYM: 10 t/ha to be applied and mixed well at the time of final land preparation.

Fertilizer N, P205 & K20-150: 60: 60 kg/ha/year should be applied along with an adequate quantity of organic matter.

Irrigation

Irrigation is given immediately after planting when planting is done on dry days.

Weeding and interculture

Lemongrass has the weed suppression capacity. One hand weeding at 25-30 days followed by one hoeing at 40-60 days after planting is enough to control weeds. After each harvesting a nominal weeding and earthing up of plants is beneficial for the next flush.

Mulching

Distillation waste (spent grass) applied as organic mulch @ 3 tons/ha in between the rows have been found very effective in controlling weeds and maintaining soil moisture as well.

Harvesting and yield

The crop is perennial in nature and gives good yields for 5 years. Harvesting is done by cutting the grass 10 cm above the ground level. During the first year of planting 3 cuttings are obtained and Subsequently, 5-6 cuttings per year are taken subject to weather conditions. The harvesting season begins in May and continues till the end of January. The first harvest is done about 90 days after planting. The interval from sowing to harvest exerts a considerable influence on the yield and the quality of oil. Both immature and over mature grass gives a lower quantity of oil. For the local type of lemon grass, the optimum interval is 40-50 days. The optimum period of harvesting, when grown on hill tops and low lying areas are 60 and 55 days, respectively. Herbage yield 15t/harvest and oil recovery about 0.3–0.5% from fresh grass can be expected. The oil is obtained by steam distillation.

Oil yield of about 350- 400 kg/ha from the second year onwards is considered satisfactory.

Extraction of Oil

The oil extracted from the wilted herb by steam distillation in stainless steel unit. The factors influencing the oil production during distillation are:

- i) Storage of the plant material
- ii) Treatment of the material
- iii) The method of distillation.

conclusion

The successful production of lemongrass depends on adopting proper cultivation practices, beginning with the selection of



high-yielding varieties and healthy planting material. Maintaining well-drained soil, timely planting, and effective nutrient and water management ensures vigorous growth and higher oil content.

Reference

New extension technologies, value addition and utilization of lemon grass (*Cymbopogon flexuosus*) essential oil.

Lemon Grass - by National Horticulture Board (NHB, India)
Production Technology of Spices, Aromatic, Medicinal Plant Crops Lemon grass (*Cymbopogon flexuosus*)
Cultivation, Oil Extraction and Chemical Composition in Kannauj Region.





Jamun: An Underutilized Fruit Crop

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Introduction

Jamun (*Syzygium cumini*) is an evergreen tropical tree belonging to the family Myrtaceae and is native to Bangladesh, India, Pakistan and Indonesia. In India it is commonly called Jambul, but it is also known by many other names, including jamblang, black plum, damson plum, duhat plum, jambolan plum, java plum and Portuguese plum. Often planted along roadsides or used as a windbreak, the Jamun tree is valued for both its resilience and its nutritional benefits. Its fruits are a good source of iron (1-2 mg per 100 g) and vitamin C and they are traditionally used to support heart and liver health. The seeds, when dried and powdered, are widely used in herbal remedies, particularly for managing diabetes.

Jamun is an important yet under-exploited indigenous fruit crop in India. It commonly grows in both wild and semi-wild forms across the country's tropical and subtropical regions. The crop is widely distributed in states such as Punjab, Haryana, Uttar Pradesh, Maharashtra, Rajasthan, Gujarat, Madhya Pradesh, Bihar, Chhattisgarh, Jharkhand, Karnataka, Kerala, Tamil Nadu and Andhra Pradesh.

Geographical Distribution

Jamun also thrives in the lower Himalayan ranges, at elevations reaching up to 1300 meters. Its cultivation extends across a large geographical belt from the Indo-Gangetic plains in the north to Tamil Nadu in the south high lighting its adaptability to diverse climatic conditions.

The Jamun tree bears fruit for 60-70 years, with fruits ripening in June-July. The berries are acidic, astringent to sweet and their deep purple colour comes from anthocyanin pigments. Ripe jamun primarily contains glucose and fructose and a medium-sized fruit provides only 3-4 calories. Jamun is valued for its strong pharmacological properties, including antioxidant, anti-hyperlipidemic, anti-diarrheal, anti-ulcer,

hepatoprotective, anti-allergic, anti-arthritis, anti-cancer, radioprotective, nephroprotective, cardioprotective, anti-pyretic, anti-neoplastic and anti-diabetic effects.

Nutritionally, jamun is a good source of iron, minerals, sugars and beneficial phytochemicals. Its sub-acidic, spicy flavour makes it popular as a fresh fruit as well as in beverages, jellies, jams, squashes, wines, vinegars and pickles.

Seasonality

Jamun trees begin flowering from March to April, producing fragrant blossoms about 5 mm in diameter. The fruits start developing in May or June, resembling large berries and the tree continues to bear fruit through July. The fruit is oblong to ovoid, initially green, then turning pink and finally



developing a glossy purple-black colour as it ripens. There is also a less common variant of the tree that yields white-coloured fruits.

Nutritive Value per 100 g of Jamun Fruit

Nutrient	Amount
Protein	0.7 g
Fat	0.3 g
Minerals	0.4 g
Fibre	0.9 g
Carbohydrates	14 g
Energy	62 kcal
Calcium	15 mg
Iron	1-2 mg
Phosphorus	15 mg
Vitamin C	18 mg
Sodium	26.2 mg
Potassium	55 mg
Magnesium	35 mg
Oxalic Acid	89 mg
Carotene	48 mg
Folic Acid	3 mg

Climate and soil

Jamun thrives in both tropical and subtropical climates due to its wide adaptability. It is a hardy species that tolerates drought, heavy rainfall and even floods and grows well in semi-arid regions with 350-500 mm annual rainfall. Young plants, however, need protection from frost. Its cultivation is suitable for arid, semi-arid, resource-poor and wasteland areas where few other crops can survive. Dry weather during flowering and fruit set is ideal, while early rains in subtropical regions help improve fruit size, colour, maturity and taste.

Jamun grows on a wide range of soils, though deep, well-drained loam that retains moisture ensures the best growth and yield. The tree also tolerates sodic, saline, ravine and degraded soils, surviving even in alkalinity up to pH 10.5. However, very heavy or very light soils are not recommended for

plantation.



Varieties

There are no officially released standard varieties of jamun in India. In North India, the commonly grown type is known as 'Rajamun', while 'Paras' from Gujarat is valued for its large fruits. Another selection, Narendra Jamun-6 from Faizabad, has been identified but is yet to gain popularity.

Under the ICAR-funded National Network Project on Underutilized Fruits (NNPUF), extensive research at CISH, Lucknow has led to the identification of several superior jamun accessions, which are now conserved in the field gene bank. The key features of these improved selections are summarized below-

1. CISH J-37: A superior selection made at Central Institute for Subtropical Horticulture, Lucknow with average fruit yield is 200- 300 kg/plant and mid-season (mature during the second week of June). The fruit is oblong and has average weight 24.05 g, pulp 92.26 per cent, TSS 16.4°Brix.

2. CISH J-42: Seedless selection by CISH, Lucknow during 2008 from Chandauli district of U.P. It was multiplied by vegetative method of propagation. Average



fruit yield is 180 - 250 kg/tree and mid-season (mature during the second week of June). The fruit is round shaped and has average weight 6.87 g, pulp 97.9 per cent, TSS 14.7°Brix and has better shelf life.

3. Jamun GJ-2: It was collected from Ode village in Anand district of Gujarat. Peak period off lowering is in March. It is an early season variety matures in the fourth week of May; fruits are oblong shaped with an average 20.0 g fruit weight, 85.00 per cent pulp, 18.0°Brix TSS, Fruit yield perplant was 28.00 kg at seventh year of age.

4. Jamun GJ-8: It was also collected from Ode village of Anand, Gujarat. The peak period of flowering is in March. It is also an early variety, fruit is oblong in shape and matures in the first week of June having 17.0 g average fruit weight, 83.33 per cent pulp, 16.0°Brix TSS, The average fruit yield is 12.00 kg/plant sixth year onwards.

5. Rajamun: It bears large-sized, oblong, deep purple fruits having purple pink, juicy and sweet pulp and small seed. Fruit matures in June-July.

6. Paras: It is a seedling selection which yields sweet fruits. Considerable tree variation exists in Pune and Ahmednagar districts of Maharashtra.

7. Konkan Bahadoli: A seedling selection developed at RFRS, Vengurla produces fruits weighing 14-16 g with 16° Brix TSS.

At CHES, Godhra (Gujarat), two varieties namely- Goma Priyanka and Thar Kranti have been released. Among these, Goma Priyanka is especially popular for its high yield, high pulp content and compact plant size, making it well suited for high-density planting.

Propagation

Seed propagation is widely used in different regions. Vegetative propagation is essential to propagate true to type plants of improved cultivars. The enormous variation found in different regions is due to sexual

propagation and cross pollination.

Selection of rootstock for vegetative propagation of jamun is important as it controls the vigour and balances the growth, yield and quality. *Syzygium densiflora* is free from termite attack, thus, it suitable for use as rootstock for *S. cuminii*. Jamun can be propagated by different techniques viz. Softwood grafting, Patch budding and Wedge grafting and Veneer grafting.

Cultivation

Planting: For seedling trees, 1 m³ pits are dug at 10 m spacing, while budded plants require 8 m spacing. Pit preparation should be completed before the monsoon or spring and each pit should be filled with topsoil and well-decomposed FYM and Compost in a ratio of 3:1. The monsoon season (July-September) is ideal for planting, though planting in February-March also gives good survival if irrigation is available. Overall, 100-150 plants per hectare can be accommodated.

Manuring and fertilization: During the pre-bearing stage, each plant should receive 20-25 kg of well-rotten farmyard manure or compost annually. Once the trees begin fruiting, the dose should be increased to 50-60 kg per plant per year. Organic manure is best applied about one month before flowering.

For fully mature trees, apply 500 g of nitrogen and 300-600 g of potassium per plant annually. These fertilizers should be spread evenly under the tree canopy and incorporated into the soil through light hoeing.

Irrigation: Plants should be irrigated immediately after manuring. Young trees need 6-8 irrigations per year to ensure healthy growth. For fruit-bearing trees, irrigation from September to October supports better fruit bud formation, while watering during May to June promotes



proper fruit development. In general, only minimal irrigation is required once the trees are established.

Canopy management

Jamun is a vigorous tree, so canopy management is essential to optimize light interception, reduce pest and disease friendly microclimates, ease cultural operations and improve overall productivity and fruit quality. Canopy management begins early through proper training to shape the plant's architecture.

Young trees should be trained to develop 3-5 well-spaced scaffold branches starting about 60 cm above the ground. Subsequent pruning helps regulate tree size and shape, create a balanced framework of primary, secondary and tertiary branches and reduce excess foliage by removing unproductive growth. Routine pruning is minimal, limited mainly to removing dry, weak or diseased branches. At CISH, Lucknow, three training systems: Open Center, Palmette and Y-shape are being evaluated for their suitability in jamun cultivation.

Harvesting and maturity indices

Seedling jamun trees begin bearing fruit at 9-10 years, while budded plants start much earlier at 5-6 years. Flowering occurs from March to April, and fruits ripen between June and July, often coinciding with the onset of the monsoon. As the fruits mature, the TSS: acid ratio and anthocyanin content steadily increase, showing a significant rise during the ripening stage.

Storage

Jamun fruit is highly perishable and typically remains in good condition for only 4-5 days at ambient temperatures. However, a seedless jamun selection identified by CISH, Lucknow has a significantly better shelf life of 5-7 days under ambient conditions and up to 20 days when stored at 4°C. This extended storage ability makes

the seedless type especially valuable for maintaining quality over longer periods.

Processing

Jamun remains largely underutilized commercially for value-added products, though its fruits can be processed into jelly, jam, juice, squash, powder, vinegar and wine. The highest yield of juice, rich in anthocyanins and other soluble compounds, can be obtained by grating the fruits and the juice can be preserved through heat pasteurization. A ready-to-serve beverage containing up to 25% juice can also be prepared. For concentrated products, juice can be processed to 30°Brix using an open pan evaporator up to 60°Brix in a vacuum concentrator, retaining quality and enhancing shelf life.

Conclusion

Jamun is a highly nutritious and medicinally valuable fruit with immense potential for cultivation across the country. Despite its adaptability, hardiness and multiple health benefits including anti-diabetic, antioxidant and cardioprotective properties, it remains an underutilized fruit crop in India. With proper selection of superior cultivars, improved propagation techniques, canopy management and post-harvest processing, jamun can be transformed into a commercially crop. Its use in value-added products such as juice, jam, squash and wine offers significant opportunities to enhance farmer income and meet growing consumer demand for health-promoting fruits. Strategic promotion and research can unlock jamun's full potential, making it a valuable component of sustainable horticulture.

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Agritourism In India

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Introduction

Agritourism is the latest concept in the Indian tourism industry. It gives the tourist an opportunity to experience the real, enchanting and authentic contact with the rural life, taste the local cuisine and get familiar with the various farming tasks during the visit. It provides welcome escape from the daily hectic life in the peaceful rural surroundings. It gives the tourist a chance to relax and revitalize in pristine natural environment, surrounded by magnificent rural scenery. The tourist gets the opportunity to see the real India and have the experience of the lifetime. Agritourism helps the child especially the urban child who normally lives in closed door school, watches television and mostly remains confined to the four walls of the home to understand and appreciate the traditional way of farming, milk production etc. Agriculture currently is under stress in terms of farmers' earnings and vagaries of nature. Through agritourism the farmer benefits by increasing his earnings and this benefit could percolate to the village community. The benefits of agritourism development are manifold. It would bring many direct and indirect benefits to the farmers and rural people as well as the tourists.

Basic Principles of Agri- Tourism

Agritourism should ensure the following three basic principles.

1. To have something for visitors to see: farms, animals, birds, flowers, fruits and trees are few things which agritourism could offer to the visitor. Apart from these, dress, culture, rural games and festivals could create enough interest among tourists in agritourism.

2. To have something for visitors to do: Participating in on-field operations, bullockcart riding, camel riding, buffalo riding, cooking, post harvest operations, participating in the rural games are few activities in which tourists can take part, learn and enjoy.

3. To have something for visitors to buy: Rural crafts, dress materials, farm gate fresh agriculture products, processed foods, medicinal value products are the few items which tourist can buy as souvenir for memory.

What is the Importance of Agritourism in India?

The importance of agritourism lies in its multifaceted benefits:

1. Economic Growth: Agritourism is an important pillar for economic, social, and environmental development. Aside from creating additional income streams for farmers by creatively exploiting their land and resources to enable unique experiences for tourists, these economically are augmen-



ted by other alternatives apart from farming.

2. Rural Development: Rural tourism promotion basically includes agritourism and all rural development which brings jobs directly or indirectly and makes the infrastructure better organized. It does encourage cultural preservation because when the local tradition, art, the festival, and local cuisine are promoted, it would still help them sustain India's rich heritage.

3. Environmental Awareness: Agritourism also raises awareness and educates visitors on sustainable farm practices and conservation efforts. It educates the need to protect the environmental resources that are very precious with ecologically sound methods.

4. Education and Awareness: Finally, agritourism closes the gap between urban town and rural communities by education and awareness about the significance of agriculture. Tourists learn to appreciate rural lifestyles, while farmers are exposed to the urban perspective, which is enriching for both sides.

Different Types of Agritourism in India

Agritourism activities are diverse and cater to different interests. The main types of agrotourism include:

1. Farm Stays: Visitors stay on working farms and participate in daily farming activities.

2. Educational Tours: Schools and groups visit farms to learn about agricultural practices, livestock management, and sustainability.

3. Agri-Adventure Tourism: Activities like tractor rides, plowing, or fishing are offered as part of a rural adventure experience.

4. Cultural Agritourism: Tourists engage with local traditions, crafts, and festivals in rural areas.

5. Eco-Agritourism: Focuses on organic farming, biodiversity, and conservation practices.

Popular Agritourism Activities in India

Agritourism activities in India have been diversified for experiencing hands-on activities as well as for giving visitors a taste of a rural lifestyle. Some such activities include:

1. Farm Tours: Exploring crop fields, orchards, and vineyards to understand agricultural practices.

2. Animal Feeding: Interacting with livestock and learning about their care.

3. Harvesting and Planting: Participating in sowing seeds, harvesting crops, or milking cows.

4. Cooking Classes: Learning to cook traditional dishes using farm-fresh produce.

5. Handicrafts and Workshops: Trying local crafts like pottery, weaving, or painting.

6. Nature Walks: Exploring the natural landscapes, bird-watching, and understanding local flora and fauna.

Agritourism in India: Key Destinations

India has true agritourism potential on account of its vast agricultural diversity. Some of the regions which host unique experiences related to agritourism are:

1. Maharashtra: Known as the pioneer of agritourism in India, the state offers farm stays, vineyard tours, and mango-picking activities.

2. Kerala: Offers paddy farming, spice plantations, and eco-tourism experiences in lush green landscapes.

3. Rajasthan: Promotes camel farming, rural fairs, and cultural tourism in desert villages.

4. Punjab: Provides opportunities to



experience wheat farming, tractor rides, and traditional Punjabi hospitality.

5. Himachal Pradesh: Known for apple orchards, tea gardens, and scenic mountain farms.

What are the Importance of Agritourism?

Agritourism right now serves as a great tool for development, socially, economically, and environmentally. The specific merits of this are:

1. For Farmers

- Diversified income sources and reduced dependency on crop yields.
- Enhanced skills and business opportunities.

2. For Tourists

- Hands-on learning experiences and a deeper appreciation for rural life.
- Authentic cultural and culinary experiences.

3. For the Economy

- Boosts local businesses and promotes regional tourism.
- Encourages investment in rural infrastructure and development.

4. For the Environment

- Promotes sustainable farming practices and conservation awareness.
- Reduces urban-rural migration by creating employment opportunities in rural areas.

Challenges in Agritourism

Despite its potential, agritourism in India faces several challenges:

1. Lack of Awareness: Many farmers and tourists are unaware of the concept and its benefits.

2. Infrastructure Gaps: Poor roads, lack of basic amenities, and inadequate

marketing limit the reach of agritourism.

3. Policy Support: Limited government support and unclear policies hinder its growth.

Overcoming challenges is possible through various awareness of campaigns, training programs, and financial support that agritourism has in India.

Conclusion

Agritourism in India is a new budding flowering niche that blends agriculture and tourism into new experiences that can benefit farmers, tourists, and the economy. It permits the visitors to pamper themselves in some of the joyful activities of agritourism, for instance, taking part in a farm tour, harvesting, and exploring traditional rites of the rural life, thus exhibiting India's flourishing agricultural heritage and the associated rich cultural diversity.

An income added besides those of the farmers is its tourism facilities as well as the conservation of their traditional practices. And with appropriate back-up and better infrastructure, it can take robust steps towards sustainable rural development as well. Since this agritourism will spur economic development, it will conserve culture and also put the tourist in an eco-friendly environment in the way of practicing sustainable practices. Promises well into closing the urban-rural divide while finding new ways to support India's agricultural economy.

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ONDC and Indian Agriculture: A New Chapter in the Digital Revolution

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Introduction

Agriculture has always been the backbone of India's economy. More than 55% of India's population is directly or indirectly dependent on farming. Yet the sector continues to face deep-rooted challenges: dependence on middlemen, limited market access and lack of real-time price discovery, high logistics costs, and insufficient digital integration.

In this backdrop, ONDC (Open Network for Digital Commerce) has emerged as a transformative opportunity for Indian agriculture. ONDC is not merely a technological framework; it is a digital ecosystem designed to democratize commerce and empower small players-including farmers, FPOs, cooperatives, and agribusinesses.

This article explains in detail how ONDC can strengthen Indian agriculture, enhance farmer incomes, and create a more open, transparent, and efficient agricultural economy.

What is ONDC? (With respect to agriculture)

ONDC is an open digital network where buyers and sellers can transact freely-without being restricted to a single e-commerce platform.

Just as UPI connected all banks and payment apps,

ONDC connects all buyer apps, seller apps, and logistics partners.

In agriculture, this means:

- A farmer can list products on ANY seller app
- A consumer can buy those products from ANY buyer app
- Delivery can be done by ANY logistics partner
- All participants follow shared open protocols

This reduces dependency, increases market access, and boosts transparency.

Key agricultural challenges that ONDC can solve

(a) Dependence on middlemen: Faculty of Veterinary Science and Animal Husbandry -Farmers often rely on multiple intermediaries before their produce reaches consumers. Each intermediary takes a commission, reducing farmers' profits.

- ONDC enables farmers to sell directly to consumers.

(b) Limited market reach: Farmers typically sell only in local mandis. They rarely get access to national markets.

- ONDC provides nationwide exposure to farmers and FPOs.

(c) Poor price discovery: Farmers often cannot compare prices across regions and markets.

- With ONDC, farmers can see real-time market prices and make informed decisions.



(d) Weak logistics infrastructure: Many farmers lack reliable transportation, causing spoilage and losses.

- ONDC integrates logistics providers, giving farmers multiple delivery options.

(e) Lack of digital skills: Traditional e-commerce platforms are complicated. ONDC simplifies the system with interoperable, user-friendly apps.

3. Major benefits of ONDC for agriculture

(a) Direct-to-Consumer (D2C) opportunities

Farmers and FPOs can list products on seller apps and sell directly to consumers nationwide—without dealing with costly marketplace onboarding processes.

(b) Higher profitability

- With reduced middlemen, Farmers earn more income
- Consumers get lower prices
- A true win-win model.

(c) Greater transparency & competition

- ONDC brings multiple buyer and seller apps together, creating healthy competition. This improves prices, efficiency, and service quality.

(d) National market access for FPOs

Over 10,000 FPOs in India often struggle to reach markets outside their region. ONDC gives them a direct gateway to:

- Sell processed foods
- Cereals & pulses
- Fruits & vegetables
- Dairy products
- Millet-based foods

(e) Boost for agritechstartups

Agri-tech startups can create solutions on ONDC for:

- Digital mandi services
- Procurement systems
- Food traceability
- Last-mile logistics
- Farm-to-home delivery

This encourages innovation in the agriculture supply chain.

(f) Potential for agricultural exports

In the future, ONDC could connect with global marketplaces, enabling Indian farmers to sell internationally.

How ONDC works in agriculture (Step-by-step workflow)

Step 1: Farmers/FPOs list products

They register on any ONDC-compatible seller app (e.g., SellerAppX, Dehaat, Mystore, Shopify-based stores).

Step 2: Consumers browse products

They shop from any buyer app (e.g., Paytm, Magicpin, PhonePePincode, Meesho).

Step 3: Logistics providers deliver

Partners like Shiprocket, Loadshare, Dunzo etc. handle shipping.

Step 4: Payment & settlement

Payments follow ONDC's secure, regulated system.

Impact of ONDC on the agricultural value chain

(1) Input Supply

Fertilizers, seeds, equipment, and pesticides can be sold digitally via ONDC.

(2) Selling farm produce

Farmers can bypass traditional mandis and list their produce online.

(3) Processing & Manufacturing

Processors can directly procure from FPOs, eliminating intermediaries.

(4) Distribution

Logistics providers integrated through ONDC ensure faster, cheaper delivery.

(5) Consumer Access

Consumers can buy fresh, traceable farm produce at better prices.

Practical use cases of ONDC in agriculture

(a) Direct sale of fruits and vegetables

Farmers and FPOs can offer fresh produce directly to urban consumers.

Examples already visible:

- Fresh vegetables listed by farmer groups on Paytm



- Millet snacks and local food items on PhonePePincode

(b) Nationwide distribution of millet-based products

After the success of the "International Year of Millets," demand has surged. ONDC can easily support national distribution for millet startups and FPOs.

(c) Organic and specialty foods

Consumers increasingly prefer organic foods. Farmers can sell:

- Organic vegetables
- Cold-pressed oils
- Millet flours
- Herbal products

Directly via ONDC platforms.

(d) Dairy & livestock products

Cooperatives and dairy startups can use ONDC to sell milk, ghee, paneer, etc., directly across cities.

(e) Sale of agricultural equipment

Agritech companies can sell:

- Drones
- Sensors
- Soil-testing devices
- Farm machinery

On ONDC, reaching a wider rural customer base.

How ONDC can help increase farmer income

1. **Direct sales** → higher margins
2. **National demand** → better price realization
3. **Digital branding** → recognition & premium pricing
4. **Competitive logistics** → lower transportation cost
5. **Selling processed products** → value addition

ONDC does not just help farmers sell—it helps them become digital entrepreneurs.

Challenges & possible solutions

1. **Digital literacy:** Training programs for farmers and FPOs are essential.

2. **Internet availability:** India's fast 4G/5G expansion is solving this challenge.

3. **Quality and packaging:** Standardization of produce and packaging is crucial.

4. **Payments and returns:** Financial literacy and support mechanisms will help farmers navigate online transactions.

The future: ONDC + Agriculture = A Digital Bharat

Over the next decade, ONDC could enable:

- A nationwide digital mandi system
- AI-driven price forecasting
- Full farm-to-fork traceability
- A unified agricultural logistics network
- Global agricultural e-commerce
- On-demand drone and mechanization services

This synergy could transform India into a global digital agriculture leader.

Conclusion

ONDC represents a new era for Indian agriculture. It is more than a digital platform—it is a transparent, open, and inclusive network designed to empower everyone from small farmers to large agribusinesses.

If implemented at scale, ONDC can help Indian farmers break free from traditional market constraints and participate in a modern digital economy.

The combination of ONDC and agriculture has the potential to turn the Indian farmer from a local seller into a nationwide digital entrepreneur. It marks the beginning of a future where Indian agriculture becomes smarter, more efficient, and globally competitive.

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Are Renewable Energies Always Green - for the Economy Too?

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Introduction

Renewable energy is widely portrayed as the cornerstone of a sustainable future. Solar panels spread across rooftops, wind turbines rising over open, lush green landscapes and hydropower stations harnessing flowing rivers have become powerful symbols of progress. In public discourse, renewable energy is often described as both environmentally friendly and economically sensible. Yet, while its environmental advantages are widely acknowledged and globally popularised, the question is whether renewable energy is always economically greener and cleaner. The answer is far more complex and noteworthy, and also it deserves careful attention.

Pre-poor Developmentalist Approach

At the operational level, renewable energy appears highly economical. Once a solar or wind power plant is installed, the cost of electricity production is remarkably low. There is no continuous fuel expenditure, unlike coal or gas-based power generation. Over the past decade, rapid technological improvements, economies of scale and global competition have dramatically reduced the cost of renewable technologies. In many regions, electricity from solar and wind is now cheaper than electricity generated from newly built fossil-fuel plants, which is not only making the environment sustainable but also helping poor peoples, specially in underdeveloped and developed countries. For consumers and policymakers alike, this makes renewables appear not only clean but also financially benefitting.

High Upfront Capital Investment & Extraction Costs

However, economic cleanliness cannot be judged solely by day-to-day operating costs. Renewable energy systems require substantial upfront investment -the manufacturing, installation and grid integration of solar panels, wind turbines, energy storage systems, transmission lines etc., require high one-time capital. These investments are to be made many years before returns are realized. For developing economies, mobilizing such large-scale infrastructural finance can be challenging and may requires to divert resources from other critical sectors such as health, education or agriculture.

Another often overlooked aspect is the cost of raw materials. Renewable energy technologies rely heavily on minerals such as lithium, cobalt, nickel, copper and some other rare earth elements. Mining and



processing these resources can be environmentally destructive, socially disruptive and economically burdensome. The shadow economic costs associated with land degradation, water contamination, health risks to mining communities, displacement of local populations etc., socio-environmental issues are rarely adjusted, hence also remain unreflected in the final price – that we pay for renewable electricity. While renewables may reduce emissions at the point of use, their upstream economic and environmental costs remain significant.

Intermittency and System-Level Economic Costs

The economic picture is also complicated by regular intermittency. Solar and wind energy depend on natural conditions – they're beyond human control. Being largely nature-dependent, electricity generation fluctuates with sunlight, wind speed, geothermal energy sourcing and seasonal patterns. To ensure a reliable power supply, energy systems may also invest in storage technologies, backup power plants and they require to install advanced grid management systems to equip it. Batteries, pumped hydropower storage and flexible grid infrastructure add substantial costs to the energy system. In some cases, fossil-fuel plants are kept operational as standby capacity, reducing the net economic and environmental gains from renewable expansion.

Policy Design

Government policies also play a crucial role in shaping the economic profile of renewable energy. Subsidies, feed-in tariffs, tax exemptions and guaranteed purchase agreements have been instrumental in accelerating renewable adoption. While such support is often justified to address the climate change and market failures, it is not without cost. These incentives are

ultimately financed by taxpayers or electricity consumers. Poorly designed subsidy regimes can lead to inefficiencies, market distortions and unnecessary fiscal pressure, raising concerns about long-term economic sustainability.

Aspect in Bioenergy

Bioenergy presents a particularly complex case. Although it is classified as renewable, its economic and environmental performance depends heavily on production methods, technological choice and availability. If biomass production competes with food crops, requires intensive inputs or leads to deforestation, its costs can outweigh its benefits. In such cases, bioenergy may fail to deliver economic expectations or environmental cleanliness.

Conclusion

So, are renewable energies always economically cleaner? The answer is nuanced. Renewable energy is essential for reducing greenhouse gas emissions, improving air quality and achieving long-term sustainability. Climate Change issues are very prominent in our India and every winter we see a surge in air quality deterioration. However, it is not automatically or universally economically cleaner in every context. A truly clean energy transition requires looking beyond headline electricity prices and considering full life-cycle costs, system-level investments, resource extraction impacts and properly formulated policy design.

Ultimately, renewable energy should be evaluated not only by how cheaply it produces electricity today but also by how effectively it contributes to long-term economic resilience, environmental sustainability and social well-being. Only through such a comprehensive and holistic perspective can renewable energy truly live up to its promise of being both green and



economically clean.

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Transforming Cardamom Processing Through Modern Drying Methods

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Introduction

As a student of horticulture, I have always heard farmers, teachers, and even traders refer to large cardamom as the “Black Gold” of the Eastern Himalayas. But it was only when I started reading about its processing, and speaking to farmers during field visits made me realize how much this single step, i.e. Curing decides the fate of the entire crop.

It can literally turn fresh green capsules into a high-value spice or a low-grade one.

This made me curious about how processing methods are changing today, especially in regions like Sikkim, Arunachal Pradesh, and parts of Nepal and Bhutan where large cardamom is a major livelihood.



Harvest Season: Where the Journey Begins

Large cardamom plants start yielding after three to four years. The harvest usually takes place from September to December, depending on altitude. Farmers look for the reddish spikes and brown seeds before cutting them using knives. Almost everyone told me the same thing: you cannot

delay drying.

Fresh capsules spoil very fast, and if the drying is not done properly, the entire effort of cultivating the crop goes to waste.

Traditional Curing: The Familiar Bhatti

For generations, farmers have used the bhatti, a mud or stone kiln, to dry their cardamom. It works by exposing the capsules to direct wood smoke. The spice gets its strong smoky aroma from here. But farmers also know the problems: cutting them using knives. Almost every farmer told me the same thing: drying should never be delayed.

- uneven drying
- very dark colour
- huge firewood requirement
- staying awake at night to feed the fire

Many farmers said that although they grow good cardamom, the drying process often reduced the market value because traders prefer a cleaner, reddish-brown colour.



The Shift Toward New Drying Technologies

This is where modern drying methods are

slowly coming in. When I compared traditional and modern systems, the differences were quite clear:

Aspect	Traditional Bhatti	Modern Dryers
Heat Source	Direct wood smoke	Hot air, solar, or electric
Temperature Control	None	Controlled (45–55°C)
Drying Time	24–36 hrs	10–15 hrs
Fuel Use	Very high	Much lower
Quality	Dark and smoky	Uniform reddish-brown
Market Value	Lower	Higher

What I found interesting is that modernization does not mean removing tradition. Instead, researchers are improving the same bhatti design so that farmers don't lose the cultural familiarity.

The Improved Bhatti: Tradition with a Small Upgrade

The Indian Cardamom Research Institute (ICRI) and state agriculture departments have introduced an improved indirect-heat bhatti. It looks almost like the old one, but with flue pipes and better insulation. The smoke doesn't directly touch the capsules, so the colour remains better. Farmers who tested it said that drying time was reduced almost by half.

Solar and Biomass Dryers: The New Experiments

Some newer ideas are also being tried in Sikkim and Arunachal Pradesh:

- Solar tunnel dryers that use UV-stabilised plastic sheets
- Biomass gasifier dryers that burn fuel more cleanly
- Hot-air or electric dryers in cooperative centres in Bhutan and Nepal

These systems give very uniform colour, which is important for export markets. Adoption is still slow because of cost and

awareness, but cooperatives are playing a big role in promoting them.

What This Shift Means for Farmers?

From a student's point of view, this modernization is not just about machines. It directly affects:

- Income from the crop
- Forest conservation (because less firewood is used)
- The shelf life and aroma of the spice
- The export potential of the region

In many villages, cardamom is the main source of yearly income. So improving even one stepcuring has a big impact on the household economy.

Conclusion

Large cardamom will always remain a heritage crop of the Eastern Himalayas. But seeing the shift from smoky, traditional bhattis to cleaner and more efficient drying systems shows how tradition and technology can work together. As students, this gives us hope that research, if communicated properly and made accessible, can genuinely improve farmer livelihoods. The future of Himalayan Black Gold seems to be moving towards a more sustainable, quality-focused direction and I feel lucky to be studying this transition as it happens.

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Water Chestnut: An Undervalued Resource in Integrated Farming Systems

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Introduction

Water chestnut (*Trapa natans* / *Trapa bispinosa*) is an aquatic crop traditionally cultivated in shallow ponds and wetlands, frequently underrepresented in contemporary agricultural strategies. Nevertheless, its compatibility with aquaculture systems, substantial nutritional profile, and ecological advantages have led to its recognition as a valuable element within Integrated Farming Systems (IFS). This article examines the agronomic potential, economic returns, associated challenges, technological advancements, and future opportunities for incorporating water chestnut into diversified farming practices.

Integrated Farming Systems (IFS) are designed to enhance productivity and sustainability by combining crops, livestock, fisheries, and other agricultural enterprises. Within these systems, water chestnut is recognized as an aquatic crop with significant potential for wetland utilization, particularly in states such as Bihar, Uttar Pradesh, and West Bengal. Its cultivation contributes to nutrient recycling, water purification, livelihood diversification, and sustainable resource management, aligning with the “Waste to Wealth” philosophy prevalent in contemporary agriculture.

Botanical and Nutritional Overview

Water chestnut (family Trapaceae) is an annual, floating aquatic plant cultivated for its edible, spiny-husked nuts.

• **Nutritional Value:** Rich in carbohydrates (22–25%) and starch (up to 70%), water chestnuts also supply essential minerals such as calcium, phosphorus, and iron, along with antioxidant bioactive

compounds.

• **Health Benefits:** Naturally gluten-free and low in fat, water chestnuts are suitable for individuals with diabetes, cardiovascular concerns, or celiac disease, and support digestive health.

• **Processing Applications:** The crop is used for starch extraction, flour, chips, and confectionery products.

Role in Nutritional Security

Water chestnut is a key dietary component in rural and low-income communities, valued for:

1. High starch content as a reliable energy source
2. Minerals (Ca, Fe, P) supporting bone and blood health
3. Gluten-free composition, suitable for special dietary needs
4. Bioactive compounds that aid immune function and digestion

Recognized as a functional food, water chestnut contributes both nutritional and medicinal benefits to local populations.



Role of Water Chestnut in Integrated Farming Systems (IFS)

Integration with Aquaculture:

Water chestnut forms a symbiotic association with aquatic organisms, enhancing fish culture. Its floating canopy moderates water temperature, absorbs excess nutrients, and suppresses algal blooms. Research indicates that integrating water chestnut with fish culture can increase fish yields by 10–15% due to improved water quality.

Nutrient Recycling and Soil Health:

The crop efficiently absorbs nitrogen and phosphorus, reducing the risk of eutrophication. Composting its biomass further enriches soil fertility, effectively closing the nutrient loop.

Wetland Utilization and Wastewater Management

Water chestnut demonstrates robust growth in stagnant or moderately polluted aquatic environments, making it an effective candidate for biological wastewater treatment and phytoremediation applications. Its high nutrient uptake capacity enables it to function as a bio-remediator, supporting phytoremediation in rural and urban water bodies.

Significance in Integrated Farming

- **Nutritional and Processing Value:** The edible bulb is rich in carbohydrates, minerals, and antioxidants, and can be processed into gluten-free flour and high-amylose starch for diverse food applications.

- **Aquaculture Synergy:** Water chestnuts are well-suited to organic-rich ponds and can be co-cultivated with fish, providing dual income streams and improving pond water quality when managed appropriately.

- **Ecosystem Services:** *Trapa* species absorb key nutrients from water, and their harvest removes these nutrients from the aquatic system, returning them to the farm as food or compostable biomass, thus

supporting nutrient cycling on small farms.

Cultivation Practices and Crop Management

Water chestnut cultivation typically begins at the onset of the monsoon. Spiny nuts (propagules) are planted either by direct broadcasting or by transplanting nursery-grown plantlets.

Practical Integrated Models for Water Chestnut Cultivation

Pond Polyculture (Fish + Water Chestnut)

Water chestnut can be cultivated along pond margins or as controlled floating mats in carp-rearing systems. Strategic planting and thinning prevent shading of fish feeding areas, and harvesting prior to heavy monsoon inflows is recommended. This approach diversifies farm income, enhances dietary options, and reduces weed and algal blooms when properly managed.

Wetland Rotation (Makhana / Water Chestnut / Fish)

In regions where makhana (*Euryale ferox*) is grown, alternating or co-cultivating shallow zones with water chestnut (*Trapa* spp.) can improve land productivity by staggering harvests and labor requirements. Recent field trials indicate compatibility with minor adjustments to cultivation practices.

On-Farm Processing Clusters

Establishing small cooperative units for drying, milling, and packaging water chestnut flour and starch can significantly increase farmer returns compared to selling raw bulbs. Trials in bakery applications show that substituting 10–20% of conventional flour with water chestnut flour yields acceptable products, creating opportunities in urban gluten-free markets.

Cultivation Practices and Crop Management

Water chestnut cultivation typically commences with the onset of the monsoon. Propagation is achieved by direct



broadcasting of spiny nuts or transplanting nursery-grown plantlets.

Cultivation Practices for Water Chestnut

- **Planting Time:** June–July
- **Plant Density:** 2–3 plants per square meter for optimal coverage
- **Water Depth:** Maintain 50–150 cm throughout the crop period
- **Nutrient Supply:** Organic manures and nutrients from fish ponds are generally sufficient
- **Harvesting:** 90–120 days after planting, when fruits turn dark and mature
- **Crop Management:** Proper thinning is essential to maintain balanced floating mats and to prevent excessive shading in fish-based systems.

Economic Significance

Yield and Profitability

- **Yield potential:** 8–12 tonnes of fresh nuts per hectare
- **Market price:** ₹ 25–40 per kg (fresh); up to ₹ 120/kg as flour
- **Net returns:** Studies from North Bihar report profit margins of ₹ 1.2–1.5 lakh/ha under integrated models (Singh and Kumar, 2019)

Value-Added Products

- **Water chestnut flour:** Used in fasting

Advantages and Disadvantages of Water Chestnut in Integrated Farming Systems

Aspect	Advantages	Disadvantages
Nutritional Value	Rich in carbohydrates, minerals, and antioxidants, gluten-free flour has a high market demand	Perishable crop; requires quick marketing or processing
Land and Water Utilization	Grows well in shallow ponds, lowlands, and wetlands unsuitable for cereals	Requires continuous water availability; not suitable for drylands
Integration with Aquaculture	Supports fish culture by improving the microclimate and utilizing pond nutrients	A dense canopy can reduce sunlight and oxygen if not managed properly
Economic	Dual income from fish and nut	Seasonal price fluctuations and

foods and gluten-free bakery products

- **Nutraceuticals:** Extracts show potential for anti-inflammatory and antioxidant applications
- **Starch and chips:** Emerging segments in agro-processing

Gender Participation and Rural Empowerment

Water chestnut farming supports women-led processing units in rural communities. Women are actively involved in peeling, drying, flour production, local marketing, vending, and managing small-scale cooperatives, contributing to household income and skill development.

Key Contributions of Water Chestnut Cultivation

- **Women's empowerment:** Supports women-led processing and cooperative units.
- **Skill development:** Provides opportunities for training in processing and value addition.
- **Increased household income:** Enhances rural livelihoods through diversified income streams.
- **Reduction in post-harvest wastage:** Promotes local processing and efficient utilization of produce.



Aspect	Advantages	Disadvantages
Return	harvest; high profit margin (₹ 1–2 lakh/ha)	market instability
Employment Generation	Creates local employment in planting, harvesting and processing	High labor demand increases cost where manpower is limited
Environmental Benefits	Acts as a bio-remediator by absorbing excess nutrients; it prevents eutrophication	It can become invasive in non-native ecosystems if unmanaged
Post-Harvest Processing	Can be processed into flour, starch, or chips; good scope for value addition	Lack of mechanization for de-husking and drying increases post-harvest loss
Soil and Nutrient Recycling	Residue biomass improves soil organic matter and nutrient cycling	Nutrient removal from ponds needs replenishment to sustain fertility
Climate Resilience	Tolerant to floods and variable rainfall; suitable for climate-smart agriculture	Sensitive to extreme cold or prolonged drought conditions
Research and Awareness	Growing interest in its use for food processing and functional products	Limited scientific research, breeding programs, and policy support

Marketing Trends and Consumer Demand

There is a notable shift toward gluten-free and organic foods, positioning water chestnut products as highly relevant in current markets.

Rapidly expanding product segments include

- Singhara flour snacks (chips, papads, fryums)
- Ready-to-cook boiled chestnuts
- Bakery products blended with singhara flour
- Nutraceuticals and health supplements
- Religious fasting foods, with demand nearly doubling during Navratri
- Effective branding, packaging, and GI tagging can further enhance market value.

Cultural and Religious Importance

Water chestnut (Singhara) holds a significant place in Indian culture:

- Commonly consumed during fasting periods such as Navratri
 - Integral to Chhath Puja in Bihar
 - Used in prasad, sweets, kheer, and halwa
 - Regarded as a pure and sattvic food
- Seasonal cultural demand provides market stability even when fresh produce prices fluctuate.

Policy Recommendations for Wider Adoption

To promote water chestnut within Integrated Farming Systems, the following measures are suggested:

- Training programs for farmers on improved cultivation practices
- Subsidy support for processing machinery
- Development of storage and cold-chain infrastructure
- Awareness campaigns highlighting nutritional benefits



- Research on high-yielding, disease-tolerant cultivars

Government support can elevate water chestnut from a seasonal crop to a commercially significant agricultural enterprise.

Recent Advancements in Research and Technology

Genetic Improvement and Breeding

Breeding programs have prioritized the development of early-maturing, high-yielding, and disease-tolerant varieties, such as *Trapa bispinosa* var. *singhara* local and *T. natans* var. *purpurea*.

Post-Harvest and Processing Innovations

The introduction of low-cost solar dryers and mechanical de-huskers by ICAR and regional universities has reduced post-harvest losses. Advances in vacuum packaging and cold-chain infrastructure have extended the shelf life of processed products by 3–4 months.

Biotechnological Applications

Research has identified bioactive compounds, including ferulic acid and catechins, positioning water chestnut as a promising candidate for functional food and cosmeceutical applications.

Integration in Climate-Smart Agriculture

Water chestnut cultivation contributes to carbon sequestration, climate resilience, and sustainable livelihoods, particularly in flood-prone areas.

Challenges and Constraints

- **Limited Awareness:** Many farmers underestimate the crop's commercial and ecological value.
- **Post-Harvest Losses:** Inadequate storage and processing infrastructure result in 20–30% wastage.
- **Labor-Intensive Harvesting:** Manual collection and de-husking remain laborious.
- **Market Volatility:** Prices fluctuate due to seasonal gluts.

- **Invasive Risk:** In non-native ecosystems, uncontrolled spread can lead to aquatic weed problems.

Future Prospects

1. Integrated Pond-Based Systems: Combining fish (carp) and water chestnut can increase per hectare returns and water productivity.

2. Mechanization: Development of small-scale harvesters and peelers will reduce labor dependency.

3. Agro-Processing Units: Establishing village-level water chestnut flour mills can generate local employment.

4. Eco-Labeling and Branding: Promoting “organic singhara” through GI tagging and sustainable certification can enhance market value.

5. Export Potential: Rising international demand for processed water chestnut flour, especially for gluten-free and fasting products, presents significant export opportunities.

Conclusion

Water chestnut is a sustainable aquatic crop offering substantial ecological, nutritional, and economic benefits. Its integration into pond-based and wetland farming systems can enhance farm income, promote nutrient cycling, and strengthen food security. With continued technological advancement, mechanization, and value-chain development, water chestnut has the potential to become a cornerstone of integrated farming systems—emerging as a valuable resource in India's agricultural landscape.

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Enhancing Horticultural Productivity with Beneficial Insect Based Pest Management

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Introduction

Horticulture (fruits, vegetables, spices, plantation and ornamental crops) is central to India's agri-growth because these crops deliver higher value per hectare than most field crops, support nutrition diversity, and generate dense rural employment. India is among the world leaders in horticulture output: official updates show total horticulture production of ~355.5 million tonnes in 2022–23, and India is the world's second-largest producer of fruits and vegetables overall. A persistent brake on productivity is insect pest pressure. Direct feeding (boring, sucking, mining) and indirect effects (virus transmission, contamination and quarantine issues) cause sizeable yield and quality losses across fruit and vegetable value chains. Strategic, evidence-based pest management is therefore essential to convert genetic potential and inputs into marketable yield. Beneficial insects—predators, parasitoids, and pollinator-allies—are central to ecologically based pest management in horticulture. When conserved and augmented, they suppress key pests, reduce pesticide reliance, and improve yield quality while maintaining ecosystem services such as pollination and nutrient cycling. This article outlines the biology of major beneficial guilds, field-ready tactics for deploying them, monitoring and decision-making frameworks, economic and environmental benefits, and practical precautions for growers. Emphasis is placed on low-cost, locally adaptable practices suitable for vegetable, fruit, spice, and floriculture systems.

India's rank in horticulture (production & highlights)

- **Overall:** India is 2nd globally in combined fruits & vegetables production (after China). It contributes approximately 10.23% of world fruit output and 14.45% of world vegetable output.

Crop-wise leadership (production share/rank):

- **Fruits:** India ranks 1st in Banana, Mango (incl. mangosteen & guava) and Papaya by

global production share.

Note on "productivity" vs "production": Productivity means yield per unit area (t/ha), while production is total output (MT).

Why beneficial insects matter in horticulture

Horticultural crops (vegetables, fruits, spices, ornamentals) are high-value but often pest-prone because of tender tissues, staggered planting, and protected cultiva-



tion. Conventional broad-spectrum sprays can create pest resurgence, resistance, and residue problems. Beneficial insects offer a self-renewing control layer that:

- Keeps key pests below economic threshold level through predation and parasitism
- Slows resistance evolution by adding non-chemical mortality
- Preserves pollinators and natural enemies, improving fruit set and quality
- Lowers input costs and residue risks, supporting safe, export-compliant produce

The main “beneficial guilds”

Predators

Predators are the species which feeds upon other animal (i.e., prey) for their development, sustenance and reproduction. They are generally larger than their prey, active and depend on more than one prey to complete their life-cycle. More than 30 families of insects are predaceous in nature and among them, the Coccinellidae, Chrysopidae, Syrphidae, Anthoridae, Staphylinidae, Cecidomyiidae, Reduviidae, Carabidae and Formicidae are important in agrihorticultural perspective. (Seni and Halder, 2022)

If we look back, the era of modern biological control also initiated with predator with the highly successful introduction of the Vedalia beetle, *Rodolia cardinalis* (Mulsant) from Australia to California to control the cottony cushionscale, *Icerya purchasi* Maskell of citrus during 1888 (Van Driesche *et al.*, 2008).

Important predators

- **Ladybird beetles (Coccinellidae):** voracious feeders on aphids, whiteflies, mealy bugs.
- **Green lacewings (Chrysoperla spp.):** larvae attack soft-bodied pests, thrips, mites, eggs.
- **Hoverflies (Syrphidae):** larvae are aphid predators; adults are excellent flower visitors.

- **Predatory mites (e.g., *Phytoseiulus persimilis*, *Amblyseius/Neoseiulus* spp.):** key for spider mite and thrips management, including in polyhouses.

- **Assassin bugs, pirate bugs, ground beetles, spiders:** generalists that stabilize pest dynamics.

Parasitoids

Parasitoids are vital components of sustainable pest management, offering an eco-friendly and effective alternative to chemical pesticides. Predominantly from the orders Hymenoptera and Diptera, these natural enemies regulate pest populations by parasitizing their hosts, contributing to ecological balance. Their ability to locate and parasitize specific pests through intricate host-parasitoid interactions makes them an essential part of integrated pest management (IPM) programs. These interactions are driven by sophisticated behavioural, physiological, and biochemical adaptations that ensure reproductive success. Several parasitoid species have proven successful in controlling major agricultural pests, leading to reduced crop losses and minimized pesticide dependence.

Important parasitoids

- **Egg parasitoids (*Trichogramma* spp.) (*T. chilonis*, *T. brasiliensis*, *T. pretiosum*, *T. bactrae*):** suppress lepidopteran borers (fruit/shoot borer, pod borer).
- **Larval/pupal parasitoids (e.g., *Bracon*, *Cotesia*, *Aphidius*, *Encarsia*, *Telenomus* and *Eretmocerus*):** target caterpillars, aphids, and whiteflies across vegetable and orchard systems.

Pollinator-allies

Although various insect species are known to play an important role in pollination, it is often assumed that honey bees (*Apis mellifera*) perform the majority of agricultural pollination services (Breeze *et al.*, 2011). Pollination by bees not only improves the fruit production and quality, but is also



considered cost effective (Kozin *et al.*, 1976).

Importance of cross pollination

Pollination is very much needed for fruit and seed production in several crops. There are several plants that cannot produce fruit and seeds by self-pollinated and need cross-pollination. In such plants, male and female parts are present either on separate plants or on separate flowers of the same plant. Cross-pollination is also necessary in where crops in which the male and female parts grow on the same flower but are physically separated. Honey bees, bats, birds and insects are important pollinators of fruits and vegetables. More than 90% of flowering plants and more than three-quarters of crops depend on animal pollination. Only 15% of the plants that make up the majority of the world's food supply are pollinated by bees, and at least 80% are pollinated by wild bees and other wildlife (Nabhan and Buchmann, 1997)

Pollination by bees increased fruit production by 50% compared to pollination by wind. Due to pollination, yield is increased in different horticulture crops are

- Lucerne - 112%
- Coriander-186%
- Carrot- 9-135%
- Raddish-22-100%
- Cole crops- 84-100%
- Onion - 93%
- Apple - 44%
- Cardamom - 21-37%
- Cucurbits – 30-100%

While primarily a pollination service, many flower-visiting insects (hoverflies, some wasps) also contribute to pest suppression or benefit from the same habitat plants used to conserve predators and parasitoids.

Other pollinators in different crops

- Mango- House flies
- Fig- female Fig wasp (*Blastophaga sp.*) (Agaonidae: Hymenoptera)

- Okra and Cotton- Bumble bees
- Yucca (starchy root vegetable)- Female incurved moth (yucca moth- *Tageticula yuccasella*)
- Brinjal- Digger bees (*Amebillavioleaceae-Apidae*)
- Tobacco- honeybee and bumble bee
- Carrot- syrphid flies and wasps

Field-ready tactics

A. Conservation biological control (make the farm friendly)

a) Flowering resource strips: Plant staggered small-headed, nectar-rich species (e.g., coriander, dill, fennel, buckwheat, marigold, sesame, mustard) along borders or as in-row islands every 20–30 m. These provide nectar/pollen to fuel parasitoid longevity and predator egg production.

b) Refugia and ground cover: Low, non-competitive covers (clovers, cowpea, grasses in alleys/orchards) protect ground predators and reduce dust that impairs natural enemies.

c) Banker plants (especially in protected cultivation): e.g., barley with cereal aphids to sustain *Aphidius* wasps; ornamental peppers for predatory bugs; castor/maize as trap/border plants.

d) Selective spraying: If thresholds are crossed, prefer soft chemistries (oils, soaps, *Bacillus thuringiensis*, *Beauveria*, pyriproxyfen, flonicamid, spirotetramat, etc.) and spot-treat evenings to spare foraging beneficials.

e) Reduce disruptive practices: Avoid unnecessary tillage and dust; maintain hedgerows; keep small water sources for adult wasps/flyes.

B. Augmentative releases (add more helpers)

- Trichogramma cards (10–50k parasitoids/ha per release, repeated at 7–10-day intervals during peak egg-laying of borers).
- Chrysoperlaeggs/larvae placed near hotspots for aphids/whiteflies/thrips.



• Predatory mites introduced early at low pest densities in polyhouses for preventive control.

• Encarsia/Eretmocerus pupae for whitefly in tomato/cucumber under protected cultivation.

Crop-pest-beneficial quick guide

Table 1: represents the effective natural enemies of pests and crops

Crop/system	Key pest (s)	Suitable beneficial(s)	Notes
Tomato, brinjal, chilli	Aphids, whiteflies, thrips; fruit & shoot borers	<i>Chrysoperla</i> , ladybirds, <i>Encarsia/Eretmocerus</i> , <i>Trichogramma</i> , syrphid flies	Combine with yellow/blue sticky traps; soft sprays.
Cucurbits	Aphids, whiteflies; melon fruit fly (eggs elsewhere)	<i>Chrysoperla</i> , hoverflies, <i>Encarsia</i> ; <i>Trichogramma</i> for leaf-feeding moths	Use lure/traps for fruit flies; floral strips boost hoverflies.
Tomato, Brinjal, Sweet Peppers, Cucumber	Spider mite; <i>Tetranychus spp.</i> (Acari: Tetranychidae)	Predatory mites such as <i>Phytoseilus persimilis</i> and several species of <i>Amblyseius spp.</i>	
Brinjal, Okra, Tomato, Papaya, Guava, Sapota, Lemon	Mealy bugs, <i>Paracoccus marginatus</i> and <i>Phenacoccus solenopsis</i> , green shield scale: <i>Pulvinaria psidii</i> (Hemiptera: Pseudococcidae) etc.	<i>Cryptolaemus montrouzieri</i> , <i>Scymnus spp.</i>	
Acid lime, Mango	Green scale, <i>Coccus viridis</i> (Hemiptera: Coccidae) on acidlime and white scale <i>Aulacaspis tubercularison mango</i> (Hemiptera: Diaspididae)	Coccinellids <i>Chilocorus nigritus</i> and <i>C. circumdatus</i>	
Tomato, potato, pepper	Tomato pinworm, <i>Tuta absoluta</i> (Lepidoptera: Gelechiidae)	Predatory mirid bugs, <i>Nesidiocoris tenuis</i>	
Cole crops	Diamondback moth (DBM), aphids	<i>Trichogramma</i> , <i>Cotesia plutellae</i> , <i>Aphidius spp.</i> , lacewings	Bt is highly compatible; avoid pyrethroids.



Crop/system	Key pest (s)	Suitable beneficial(s)	Notes
Citrus, mango	Tephritid fruit flies	<i>Fopius arisanus</i> , <i>Diachasmimorpha kraussii</i> , <i>D.troini</i>	
Okra	Jassids, whiteflies, fruit/ shoot borers	<i>Predatory bugs</i> , <i>Encarsia</i> ; Trichogramma	Border marigold can help disrupt pests.
Orchard (mango, litchi, citrus, guava)	Scales, mealybugs, fruit borers, aphids	<i>Ladybirds</i> , <i>lacewings</i> , <i>parasitoids</i> (e.g., <i>Anagyrus</i> , <i>Aenasius</i>), <i>predatory mites</i>	Prune for airflow conserve ant predators protect scales.
Protected cultivation	White flies, thrips, mites	<i>Encarsia</i> , <i>Eretmocerus</i> , <i>Amblyseius/Neoseiulus</i> , <i>Phytoseiulus</i>	Essential to start early and control dust/ weed hosts.

Monitoring and decision-making

1. Scouting: Inspect undersides of 20–30 leaves per block weekly; record pest and natural enemy counts.

2. Decision thresholds: Act when pests approach crop-stage-specific economic thresholds and beneficial:pest ratios are unfavorable (e.g., aphids rising while hoverfly/parasitoid mummies remain low).

3. Simple tools:

- Sticky traps (yellow for whiteflies/aphids; blue for thrips) at canopy height.
- Beating trays for thrips/mites; hand lens for parasitoid mummies and mite predators

4. Post-spray check: Re-scout 3–5 days after any intervention; avoid repeated broadspectrum applications that collapse natural enemy populations.

Implementation blueprint (smallholder to commercial)

Plan: Map hotspots from the previous season. Choose 2–3 flowering species that cover early, mid, late windows.

Prepare: Source quality biocontrol agents (cards, mites, parasitoids) from accredited suppliers; verify emergence rates.

Plant: Establish floral strips 2–3 weeks before peak pest season; install banker

plants in polyhouses.

Release: Time Trichogramma with first moth catches (pheromone traps) and repeat. Introduce predators/parasitoids early at low pest densities.

Protect: Use selective inputs; avoid tank mixes with broad-spectrum insecticides; apply at dusk; keep a no-spray buffer around floral strips.

Record: Maintain a simple log of pest counts, beneficial counts, sprays, and yields. This demonstrates ROI and guides next season's plan.

Economics and co-benefits

Lower input costs: Fewer insecticide sprays, less PPE and application labor.

Yield and quality: Better fruit set and lower blemishes; export-friendly residues.

Resistance management: Diversifies mortality factors, extending life of selective chemistries.

Ecosystem services: Pollinator support, soil biodiversity, and landscape resilience.

Conclusion

Beneficial insect-based pest management represents a cornerstone of sustainable horticultural production. Predators, parasitoids, and pollinator-allies collectively



regulate pest populations, enhance crop pollination, and reduce reliance on broad-spectrum chemical pesticides. Their integration into conservation and augmentative biological control strategies supports stable yields, improved produce quality, and long-term agro-ecosystem resilience. Field-ready practices such as flowering resource strips, selective pesticide use, banker plants, and timely releases of natural enemies are practical, cost-effective, and adaptable across open-field and protected cultivation systems. By strengthening ecological processes rather than replacing them, beneficial insects contribute to resistance management, residue-free produce, and environmental safety. Wider adoption, supported by farmer training and location-specific recommendations, can significantly advance sustainable horticulture while meeting food security, export quality, and biodiversity conservation goals.

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Coco Peat is Option of Soil

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Introduction

Coco Peat, also known as coir pith, coir fibre pith, coir dust or simply coir is an ideal growing media for horticultural and agricultural applications made from coconut husks. It makes an excellent growing medium for hydroponics, soil mixes and container plant growing. coco peat is an excellent option for soil, acting as a soil substitute or amendment known for superior water retention, aeration, and sustainability, making it ideal for potting, seed starting, and improving soil structure for healthier roots, especially in urban or container gardening. It's lightweight, pH-neutral (5.5-6.5), and improves nutrient absorption, though it's often best used mixed with soil or compost for balanced nutrition and root anchoring. Coco peat is 100% organic and is widely used in horticulture and agriculture due to its unique characteristics.

Advantages of using Coco Peat

1. It can be used in seed in starting mixes, bedding plants, soil mixes, gardens and container plants.
2. It is free from any bacterial and fungal growth and is supposed to be very inert material thereby making it a suitable growing media especially in gardens and Green house agriculture where high hygienic conditions are required.
3. Coco peat holds water rather than shedding it like traditional peat does! It holds 8 - 9 times its weight in water.
4. It has the ability to release nutrient to plants for extended period of time.
5. It has a great oxygenation properties which is important for healthy root development.
6. It has a pH of 5.0 - 6.8 which is neutral to slightly acidic. This makes it great for alkaline garden soils.
7. Coco peat can even be reused for up to 4 years.
8. Easy to use: Just put your compressed coco peat block in a container, add 4 quarts of warm water and let it sit until the water is absorbed, fluff it up and you are ready to use coco peat
9. Vermiculture: Coco peat makes a great bedding material for worm bins. It is actually good for them and increases worm growth by 25%.
10. Coco peat products are reptile bedding and roof top gardening. Being a good absorbent, dry coco peat can be used as an oil absorbent on slippery floors.
11. Washed coco peat has an EC of 1.5 - 1 mS/cm in 1:1.5 dilution. It is one of the components of ecologically responsible cultivation (Organic substance ideal for



ORGANIC AGRICULTURE).

12. Cocopeat contains lignin, cellulose and hemi-cellulose. Lignin helps the product to remain stable and retain its positive properties for several years as it ideal for reuse.

13. It is very easy to handle.

Preparation of Coco peat for use

1. Put compressed coco peat block in a container

2. Add 4 quarts of warm water and let it sit until water is absorbed.

3. Fluff it up and it will be ready for use.

- **Water Retention:** Holds 6-8 times its weight in water, reducing watering frequency.

- **Aeration:** Its fibrous structure creates air pockets, promoting healthy root growth.

- **Lightweight:** Reduces weight in pots, ideal for balconies and rooftops.

- **pH Balanced:** Neutral pH (5.5-6.5) suits most plants, improving nutrient uptake.

- **Sustainable:** Eco-friendly alternative to peat moss, made from coconut husks.

- **Pest Resistant:** Naturally resistant to some pests and diseases.

How to Use It

- **As a Substitute:** Can be used alone in hydroponics or soilless setups, especially for lighter plants.

- **As an Amendment:** Mix with soil and compost (around 20-30%) to lighten heavy soils and boost moisture.

- **Seed Starting:** Excellent for germination and rooting cuttings due to moisture and aeration.

- **Mulch:** Apply on top of soil in pots to retain moisture and regulate temperature.

Physical Properties

- Cocopeat is a lightweight, organic growing medium known for superior water retention (holding 8x its volume), excellent aeration for root health, and a neutral to slightly acidic pH (5.5-6.5). Key properties

include high Cation Exchange Capacity (CEC) for nutrient holding, natural fungal resistance, low Electrical Conductivity (EC) in quality products, and slow decomposition, making it a sustainable, reusable alternative to peat moss. It's low in nutrients, requiring fertilization, but improves soil structure and prevents compaction, fostering strong root growth and reducing watering.

- **Lightweight & Porous:** Easy to handle and provides excellent air pockets.

- **High Water Retention:** Spongy structure holds significant moisture, reducing watering frequency.

- **Aeration:** Prevents soil compaction, allowing roots to breathe and develop.

- **Slow Decomposition:** Resists breakdown, providing long-lasting support.

Chemical Properties

- **pH Level:** Neutral to slightly acidic (around 5.5 - 6.8), ideal for most plants.

- **Nutrient Profile:** Low in NPK but good at holding nutrients due to high CEC; requires added fertilizer.

- **Low EC:** High-quality coco peat is salt-free.

Biological Properties

- **Disease Resistance:** Natural antifungal properties fight soil-borne diseases.

- **Free of Pathogens:** A clean growing medium, free from weeds and harmful microbes.

Environmental & Usage Properties

- **Eco-Friendly:** A renewable byproduct of the coconut industry, biodegradable.

- **Versatile:** Used alone or mixed with soil to improve structure, aeration, and moisture.

- **Reusable:** Can be used for multiple growing cycles.

Conclusion

Coco peat is a highly effective, eco-friendly



growing medium that offers superior water retention, aeration, and soil conditioning, making it an excellent sustainable alternative to peat moss for healthier plants, reduced watering, and better yields in various applications like hydroponics, urban gardening, and general horticulture, paving the way for more sustainable farming practices.

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Ninjacart: A Revolutionary Agritech Model Transforming India's Agricultural Supply Chain

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Introduction

India is one of the world's largest agrarian economies where nearly 55% of the population depends directly or indirectly on agriculture. Although agricultural production is high, farmers often fail to receive fair prices for their produce. The primary reason behind this contradiction is the weak, unorganized and inefficient agricultural supply chain. Traditional mandis, layers of middlemen, unstable prices, high wastage, transportation issues, and lack of market information prevent farmers from earning profitable returns.

In this scenario, agritech startups like Ninjacart introduced technology-driven solutions that transformed the entire supply chain. Ninjacart created a transparent, faster, data-driven and efficient farm-to-retail system that benefits farmers, retailers and consumers. This article presents a detailed discussion on the origin of Ninjacart, its functioning, technology, impact on farmers, achievements, challenges, and future prospects. It also highlights how Ninjacart stands as a benchmark for modernizing India's agricultural ecosystem.

Origin and Establishment of Ninjacart

Ninjacart was founded in 2015 by Thirukumaran Nagarajan, Vasanth Kumar and their team. Initially, it began as a B2C service delivering fresh fruits and vegetables directly to consumers. However, within a few months, the founders realized that the main issue was not consumer access but the breakdown and inefficiency of the agricultural supply chain.

Thus, the company shifted from a B2C model to a B2B agritech supply chain model, directly connecting farmers with retailers. This change transformed the startup's growth trajectory, making Ninjacart one of

India's most impactful agritech success stories.

Ninjacart started operations in Bengaluru but gradually expanded to several Indian states. Today, it operates in more than 50 cities, connecting thousands of farmers with tens of thousands of retailers.

How Ninjacart Works (Operational Model)

The functioning of Ninjacart is based on eliminating middlemen and establishing a direct link between farmers and retailers. The entire system is fast, scientific and completely data-driven.

Key Stages of the Operational Model

(1) Direct Procurement from Farmers



Farmers bring their produce to Ninjacart's nearby Collection Centres.

- No middlemen
- No hidden commissions
- Transparent weighing and instant digital payment

(2) Sorting, Grading and Quality Check

Produce is graded and sorted immediately after procurement.

- A-grade
- B-grade
- C-grade

AI-enabled systems help detect spoiled or low-quality produce.

(3) Micro Warehouses / Distribution Centres

The produce is temporarily stored in small warehouses close to the city, ensuring freshness and minimal wastage.

(4) Delivery to Retailers

Ninjacart delivers the sorted produce to retailers, hotels, restaurants and supermarkets within 6–12 hours.

(5) Digital Tracking System

Every step of the supply chain is monitored through mobile apps and software:

- Real-time tracking
- Stock updates
- Price stability
- Demand forecasting
- Digital payments

This digital ecosystem makes the supply chain fast, transparent and cost-effective.

Ninjacart's Network and Impact (With Statistics)

Ninjacart's expansion can be understood through the following data:

Category	Data (Approx.)
Cities Covered	50+
Farmers Connected	100,000+
Retailers Using the Service	80,000+
Daily Produce Handled	1,400+ tons

Category	Data (Approx.)
Warehouses & Collection Centres	1,200+
Average Delivery Time	12 hours
Wastage Reduction	From 30% → to 4–5%

These figures prove that Ninjacart has achieved a significant and measurable impact on India's agricultural supply chain.

Benefits for Farmers

Ninjacart's biggest contribution is improving the economic condition of farmers. Many issues associated with traditional market systems have been successfully addressed.

Major Benefits for Farmers

(1) Higher Prices (15–20% Increase)

Farmers earn better rates compared to mandis because the chain does not involve middlemen.

(2) Instant Digital Payments (Within 24 Hours)

Farmers receive guaranteed, fast and secure payments.

(3) Better Demand Forecasting

Ninjacart provides insights about market demand, helping farmers plan their crops efficiently.

(4) Lower Transportation Costs

In many places, Ninjacart arranges pickup, reducing the farmer's burden.

(5) Reduced Wastage

Fast movement of produce results in lower spoilage.

Benefits for Retailers (Shopkeepers)

Ninjacart is equally beneficial for small retailers, supermarkets and restaurants.

Advantages for Retailers

- Daily access to fresh produce
- Stable and transparent pricing
- Availability of multiple items at one place
- High-quality, graded produce



- Easy app-based ordering
 - Timely delivery every morning
- This improves business stability, reduces uncertainty and increases customer satisfaction.

Technology Used by Ninjacart

Ninjacart is not just a logistics company; it is a tech-driven platform built on advanced digital infrastructure. The use of technology is the backbone of its success.

Key Technologies

(1) AI-based Demand Forecasting

AI predicts which produce will be in demand, reducing supply mismatch.

(2) Route Optimization Algorithms

Software identifies the fastest, most fuel-efficient delivery routes.

(3) Warehouse Automation

Sorting, grading and packaging are partially automated for accuracy and speed.

(4) Digital Ledger and Online Payments

A transparent record of every transaction builds trust.

(5) Traceability System

Produce can be tracked from the farm to the consumer.

These innovations help Ninjacart maintain quality, speed and reliability.

Transformation in India's Agricultural Supply Chain

Ninjacart introduced several systemic changes in India's agricultural sector.

Major Changes Brought by Ninjacart

1. Reduction in the number of middlemen
2. Farm-to-market time reduced from 2–3 days to 12 hours
3. Wastage dropped from 30% to nearly 4–5%
4. Stable pricing in markets
5. Farmer incomes increased by 15–20%
6. Increased transparency and trust in the supply chain

These changes have modernized and strengthened the agricultural economy.

Challenges Before Ninjacart

Despite its success, Ninjacart faces several challenges.

(1) Limited Digital Adoption in Rural Areas

Many farmers still hesitate to use digital tools.

(2) Insufficient Cold-Chain Infrastructure

To expand further, the company needs more temperature-controlled storage units.

(3) Weather and Road Conditions

Heavy rains and poor rural roads disrupt logistics.

(4) Limited Reach Among Small Farmers

Reaching remote farmers remains a challenge.

Future Prospects of Ninjacart

Ninjacart is working on several future-focused initiatives that may deeply transform agriculture.

(1) Expansion into Global Exports

Developing a farm-to-global-market system for Indian produce.

(2) Input Supply to Farmers

Providing seeds, fertilizers, pesticides and tools directly to farmers.

(3) Credit and Insurance Services

Offering affordable loans and crop insurance.

(4) Global Expansion of Supply Chain Technology

Sharing its technology with other developing countries.

These initiatives will further boost farmer incomes and modernize the sector.

Conclusion

Ninjacart has revolutionized the Indian agricultural supply chain by combining technology, logistics and data-driven systems. It proved that digital innovation can solve long-standing issues in farming. The company has significantly improved farmers' incomes, reduced wastage, increased transparency and made high-quality



produce available to retailers.

Ninjacart is not just a business; it is a movement towards modernizing Indian agriculture. Its success showcases how agritech can uplift millions of farmers while strengthening the economy. With expanding networks, advanced technology and a farmer-first approach, Ninjacart is poised

to shape the future of agriculture in India and inspire similar models across the world.

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Biodigesters: A Comprehensive and Sustainable Solution for Organic Waste Management

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Introduction

The exponential generation of organic waste stemming from rapid urbanization, intensive agriculture, and industrial food processing has severely strained global waste management infrastructure. Traditional disposal methods, such as open dumping, landfilling, and incineration, contribute significantly to climate change through the unabated release of methane (a GHG with a global warming potential significantly higher than carbon dioxide) and groundwater contamination via toxic leachate.

Anaerobic digestion (AD) has emerged as a scientifically robust and commercially viable technology to combat these issues. Biodigesters utilize this natural biological process, occurring in an oxygen-free environment, to break down complex organic matter. The dual output of this process—biogas and digestate—aligns perfectly with the principles of a circular economy, shifting the paradigm from waste disposal to resource recovery.

Feedstock Selection and Pre-treatment

The efficiency of a biodigester is fundamentally dictated by the quality and composition of its feedstock. Common organic substrates include agricultural residues, animal manure, municipal solid waste (MSW), food waste, and wastewater sludge.

Because organic waste can be highly complex, pre-treatment is often required to accelerate the degradation process and maximize biogas yield:

- **Mechanical Pre-treatment:** Shredding, milling, or grinding the feedstock to reduce particle size, thereby increasing the surface area available for microbial attack.

- **Thermal Pre-treatment:** Heating the feedstock (often between 70°C and 160°C) to break down cell walls and solubilize complex carbohydrates and proteins.

- **Chemical/Biological Pre-treatment:**

Using alkalis, acids, or specialized enzymes to break down recalcitrant lignocellulosic materials (like crop stalks and wood chips) that are otherwise difficult for bacteria to digest.

The Biochemical Process of Anaerobic Digestion

The decomposition of organic matter in a biodigester is not a single reaction, but a complex, four-stage syntrophic cascade involving specialized microbial consortia:

1. **Hydrolysis:** Hydrolytic bacteria secrete exoenzymes to break down insoluble organic polymers (carbohydrates, lipids, proteins) into soluble monomers (sugars, fatty acids, amino acids). This is often the rate-limiting step for solid waste degradation.



2. Acidogenesis: Acidogenic bacteria convert these soluble monomers into volatile fatty acids (VFAs), alcohols, hydrogen, and carbon dioxide. A rapid accumulation of VFAs can lead to a drop in pH, potentially stalling the system.

3. Acetogenesis: Acetogenic bacteria further digest the products of acidogenesis—specifically longer-chain VFAs like propionate and butyrate—into acetic acid, carbon dioxide, and hydrogen.

4. Methanogenesis: Strictly anaerobic archaea synthesize methane in the final step. *Acetoclastic methanogens* split acetic acid into methane and carbon dioxide, while hydrogenotrophic methanogens use hydrogen to reduce carbon dioxide into methane.

Synergistic Effects of Co-digestion

Historically, biodigesters processed a single type of waste (e.g., only cow manure). Modern facilities increasingly utilize Anaerobic Co-digestion (AcoD) the simultaneous digestion of two or more complementary feedstocks.

- **Benefit:** Co-digestion balances the carbon-to-nitrogen (C:N) ratio, dilutes inhibitory substances (like ammonia from poultry manure), improves moisture content, and significantly boosts overall biogas yield due to positive synergistic effects among the microbial communities.

Types of Biodigesters

Biodigester engineering varies based on capital, location, and the physical state of the feedstock (wet vs. dry AD).

Table 1: Comparison of Industrial and Small-Scale Biodigesters

Digester Type	Key Characteristics	Advantages	Disadvantages	Typical Applications
Fixed-Dome	Underground masonry structure with fixed gas storage.	Low maintenance, highly durable, well-insulated.	Variable gas pressure, difficult to repair leaks.	Rural households, small farms.
Continuous Stirred-Tank Reactor (CSTR)	Vertical cylindrical tanks with mechanical or hydraulic mixing	Excellent homogenization, high biogas yield, continuous operation.	High capital and energy costs, risk of short-circuiting.	Municipal wastewater, large dairy farms, food processing.
Plug-Flow Reactor	Horizontal, tubular reactor where waste moves as a discrete "plug."	Ideal for high-solids waste (dry AD), no active internal mixing required.	Prone to crust formation, poor temperature uniformity.	Ruminant manure, concentrated agricultural waste.
Covered Lagoon	Large anaerobic pond fitted with an impermeable gas-tight cover.	Very low capital cost, handles large volumes of dilute waste.	Requires vast land area, lower efficiency in cold climates.	Palm oil mill effluent, large swine operations.

Optimization and Control Parameters

To prevent system failure (often termed

"digester souring"), operators must closely monitor environmental variables to ensure the microbial consortia thrive.



Table 2: Key Operational Parameters for Anaerobic Digestion

Parameter	Optimized Range	Significance and Impact
Temperature	Mesophilic (35°C-40°C); Thermophilic (50°C-60°C)	Thermophilic systems offer faster degradation and better pathogen destruction but are highly sensitive to temperature fluctuations.
pH and Alkalinity	pH 6.8 – 7.2	Methanogens are severely inhibited at a pH below 6.5. High alkalinity (buffer capacity) is required to neutralize the acids produced during acidogenesis.
C:N Ratio	20:1 to 30:1	Too much nitrogen causes ammonia toxicity (lethal to methanogens); too much carbon starves the bacteria of essential structural nutrients.
Organic Loading Rate (OLR)	2 - 5 kg VS/m ³ /day (varies by system)	The daily input of volatile solids. Overloading overwhelms the methanogens with acids, halting gas production.
Hydraulic Retention Time (HRT)	15 - 40 days (mesophilic)	The average time waste spends inside the reactor. Must be long enough to allow slow-growing methanogens to reproduce and avoid "washout."

Upgrading Biogas to Biomethane

Raw biogas typically consists of 50-70% methane, 30-50% carbon dioxide, and trace amounts of hydrogen sulfide and siloxanes. While raw biogas can be burned in specialized engines for electricity and heat (CHP - Combined Heat and Power), modern facilities increasingly focus on biogas upgrading. By removing carbon dioxide and impurities through processes like water scrubbing, membrane separation, or pressure swing adsorption (PSA), the gas is purified into biomethane (>95% methane). Biomethane is a direct drop-in replacement for natural gas and can be injected into national gas grids or used as compressed natural gas (CNG) for heavy-duty transportation.

Economic Viability and Market Potential

The financial sustainability of a biodigester project relies on multiple revenue streams:

- **Tipping Fees:** Revenue collected for taking in and managing municipal or industrial organic waste.
- **Energy Sales:** Selling electricity to the grid or selling upgraded biomethane to natural gas distributors.
- **Digestate Commercialization:** Processing the nutrient-rich digestate into pelletized, commercial-grade organic fertilizers.
- **Carbon Credits:** Earning and selling Renewable Identification Numbers (RINs) or carbon offset credits for mitigating methane emissions and displacing fossil fuels.

Environmental and Social Benefits

- 1. Decarbonization of Energy Networks:** Provides a reliable, dispatchable source of renewable baseload energy, complementing intermittent renewables like solar and wind.
- 2. Methane Abatement:** Captures passive methane emissions that would otherwise escape from rotting manure piles or landfills.



3. Soil Remediation: Digestate contains stabilized organic matter and readily available nitrogen, phosphorus, and potassium (NPK), which restores depleted soils and reduces reliance on energy-intensive synthetic fertilizers.

4. Decentralized Energy Security: Empowers rural communities and remote industrial plants to become energy-independent.

Challenges and Future Outlook

Despite clear advantages, several barriers remain:

- **High Initial CapEx:** Industrial-scale CSTRs and biogas upgrading equipment require massive upfront investment.
- **Inhibitory Compounds:** The presence of heavy metals, antibiotics, or microplastics in the feedstock can disrupt the biological process and contaminate the final digestate.
- **Grid Infrastructure:** A lack of localized natural gas pipelines or electrical grid access can limit the ability to sell produced energy.
- **Policy Gaps:** Inconsistent governmental subsidies and regulatory hurdles regarding digestate usage as a certified fertilizer often slow down industry growth.

Future research is heavily focused on *microbial community engineering* (bioaugmentation), integrating artificial intelligence to predict and optimize digester health, and exploring the integration of AD with dark fermentation for bio-hydrogen production.

Conclusion

Biodigesters represent a mature, scalable, and indispensable technology in the global transition toward a circular economy. By bridging the gap between organic waste management and renewable energy production, anaerobic digestion tackles multiple Sustainable Development Goals simultaneously. While economic and technical

challenges persist, advancements in co-digestion, biogas upgrading, and automated monitoring are rapidly improving the commercial viability of biodigesters. With the right policy frameworks and infrastructural investments, biodigesters will play a foundational role in achieving global net-zero emission targets.

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Boosting Farmer Incomes through Profitable Flower Farming

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Introduction

The floriculture and landscape industry in India is witnessing a significant transformation, emerging as a profitable, sustainable, and viable alternative to traditional agriculture. Driven by rising incomes, rapid urbanization, and changing consumer preferences, flower farming is increasingly contributing to rural development and enhanced farmer incomes. Currently, India has over 285,000 hectare sunder floriculture cultivation, producing a wide variety of loose and cut flowers. Floriculture offers considerably higher returns per hectare than many traditional crops and is generating employment opportunities, particularly for rural youth and women. The sector is further supported by the expansion into allied services like landscape design, greenhouse development, maintenance, and retail floristry. Government policies, liberalization of trade and investment in cold-chain infrastructure have also bolstered the growth of export-oriented floriculture units. Despite progress, the marketing system remains largely unorganized, relying on inefficient methods for packaging, storage, and transport. However, ongoing reforms are focusing on improving infrastructure and establishing organized marketplaces to streamline the supply chain. Beyond its economic value, flowers hold cultural and emotional significance in Indian society, being central to ceremonies, festivals, and personal expressions. Moreover, ornamental plants contribute to urban greening, landscape beautification and pollution control, highlighting their environmental value. Globally, the floriculture industry is valued at USD 57.5 billion (2024) and is projected to grow to USD 109.1 billion by 2034. India accounts for approximately 35% of the global area under floriculture cultivation, positioning itself as a key player alongside other Asian nations like China and Thailand. As traditional exporters like the Netherlands and the USA face stagnation, India is leveraging increasing international demand to strengthen its presence in the global floral economy.

Global Trends and India's Growing Role

Floricultural crops include bedding plants, houseplants, flowering garden plants, potted plants, cut flowers, and cut cultivated greens. Flowers are primarily used for decoration, aesthetic purposes, and

as a means of expressing greetings. Their association with prosperity and well-being contributes to the growth of the global floriculture market. Globally, more than 145 countries are engaged in the floriculture industry. According to recent data from



Future Market Insights (FMI), the global floriculture market is valued at USD 57.5 billion in 2024 and is projected to reach USD 109.1 billion by 2034, growing at an annual rate of 10%. Among the top fifteen flower-importing countries, Singapore recorded the highest significant positive growth rate in export quantity, at 14.18% (significant at the 1% level). Approximately 45 to 50 countries are involved in large-scale floriculture production. In terms of production value, the leading countries include Thailand, the Netherlands, the United States, the United Kingdom and China. Conversely, countries such as the United States, Australia, Italy, and the Netherlands have experienced a significant negative growth rate in the sector. According to the International Association of Horticultural Producers, global flower production covers an area of 702,383 hectares. Of this, Europe accounts for 48,705 ha, North America for 21,067 ha, Asia for 523,829 ha, the Middle East for 4,026 ha, Africa for 7,604 ha, and Central and South America for 97,152 ha.

As per the Indian Horticulture Database, India had 285,000 hectares under floriculture cultivation in 2023–24, representing approximately 35% of the global production area.

The global floriculture industry is undergoing rapid transformation driven by globalization and economic development in various regions. This has also intensified international competition. Traditional flower-producing countries such as the Netherlands, the United States, Colombia, Japan, and Italy continue to play a major role, while Asian nations including India, China, Bangladesh, Thailand, and Vietnam are steadily expanding their horticultural output. Additionally, floriculture production is growing rapidly in Latin America and Africa. The primary flower-consuming

markets are concentrated in Western Europe and North America. Globally, rising socio-economic standards have led to increase per capita flower consumption, which directly supports the growth of the floriculture industry. This rising demand has encouraged the development of new production hubs in Asia and Africa, regions that were previously overshadowed by traditional markets in Europe and the USA.

In Asia, India, China, and Thailand are emerging as key players in the global floriculture sector. Over the past two decades, India has made significant strides in entering the international flower market. The area under flower cultivation in the country has been expanding steadily, reflecting growing domestic and international demand.

Emerging Trends in Floriculture and Landscaping

Floriculture has made appreciable growth in the last three decades as commercial venture. Floriculture production in India covers 285,000 hectares with a production of 2,284,000 tonnes loose flowers and 947,000 tonnes cut flowers every year (2023-24). There is transformation in business to landscape design, contracting and maintenance services, wholesale and retail sales, development of parks and leisure places, gardens, greenhouses including various greenhouse inputs besides providing technical advices. Our country has exported 19,677.89 MT of floriculture products worth ₹ 717.83 Crores/ 86.63 Million USD in 2023-24 to the world. The USA, the Netherlands, United Arab Emirates, UK, Canada and Malaysia were major importing countries of Indian floriculture produce. New distribution structure with the aid of IT is likely to be in place, which would be emphasizing a hi-tech production system, virtual market, branding, cataloguing and quality



assurance.

Floriculture and landscape have become a part of modern lifestyle and is being utilized in floral decorations, floral craft, and interior-scaping and commercial premises. Floriculture (includes cut flowers, loose flowers, bedding plants, potted plants, hedges, value added products etc.) has made appreciable growth in the last three decades as commercial venture. Now the use of floricultural produce is no longer confined to religious purposes alone. Lifestyle floriculture has now emerged as business activity involving production of ornamental plants, cut flowers, turf, and foliage and delivers a range of services. There is transformation in business to landscape design, contracting and maintenance services, wholesale and retail sales, development of parks and leisure places, gardens, greenhouses including various greenhouse inputs besides providing technical advices.

Floriculture- A Pathway to Youth Employment and Rural Development

Floriculture, being a labour-intensive sector, holds immense potential to generate employment for rural communities and unemployed youth. As India experiences its demographic dividend with nearly 40% of the population comprising young individuals there is an urgent need to harness this youth potential productively. One of the nation's pressing challenges is to create sustainable livelihoods and income-generating opportunities, especially in agriculture. A critical question arises: who will be farming in the years to come? The biggest challenge lies in retaining and attracting the younger generation to agriculture. Unless farming is made intellectually stimulating and economically viable, it will be difficult to engage rural youth in this sector. Floriculture offers a promising solution. The income and

employment generated through flower cultivation are significant, offering new dimensions to the horticultural industry. With the evolution of horticulture, its growth has expanded from traditional rural borders to urban and peri-urban areas, marking a transformation in both scale and scope. This shift underscores the potential of flower crops to contribute meaningfully to rural development and help in doubling farmers' incomes.

Marketing of Cut Flowers in India

The marketing of cut flowers in India remains largely unorganized. In most Indian cities, flowers are transported to wholesale markets, which are typically held in open courtyards. From these wholesale hubs, flowers are distributed to local retailers, many of whom operate from roadside stalls using large buckets to display a variety of flowers. However, in larger cities, there are well-established florist showrooms offering value-added services and storing flowers under controlled temperature conditions to maintain freshness.

Recognizing the potential of this sector, the government is investing in the establishment of auction platforms and organized retail outlets equipped with proper storage facilities to extend flower shelf life. Despite these developments, packaging and transportation methods from farm to market remain largely unscientific and inefficient. Depending on the flower variety, packaging materials range from burlap sacks and bamboo baskets to basic cardboard boxes or even old newspapers. Flowers are transported by road, rail, or air, often without temperature regulation.

To address these challenges, the government has introduced support measures, such as subsidies for refrigerated cargo vehicles and the development of export-oriented units equipped with modern infrastructure,



including pre-cooling facilities.

Growth and Opportunities in Ornamental Horticulture

The growth of ornamental horticulture has not only created new opportunities in floriculture farming but has also contributed significantly to improving livelihoods, often more so than traditional crops. This sector's expansion has also opened up promising business prospects in various allied industries, such as specialized transportation, the production and supply of related products like nursery bags, pots, potting media, tools, plant protection materials, and other equipment. This progress can be attributed to the foresight of policy planners who, in collaboration with various stakeholders in the floriculture sector, provided strategic direction that has led to the sector's robust and sustainable development.

Marketing Margins in Floriculture

Marketing margins refer to the price differences observed at various stages of the marketing chain. These margins are calculated using data collected on prices at different levels - from producers to consumers. The marketing profit margin for each intermediary is determined by the absolute profit margin or price spread, which represents the difference between the price received and the price paid by that intermediary.

Conclusion

Floriculture in India has emerged as a transformative force in the agricultural landscape, offering a profitable, sustainable and employment-rich alternative to traditional farming. With rising domestic and international demand, expanding cultivation areas, and increasing integration with allied services like landscaping, green house management, and retail floristry, the sector presents immense potential for enhancing farmer incomes and rural livelihoods. Government support through policy incentives, infrastructure development and export facilitation has laid a solid foundation for continued growth. However, challenges such as unorganized marketing, inadequate cold-chain logistics, and inefficient packaging must be addressed through innovative solutions and public-private partnerships. Encouraging youth and women's participation, promoting hi-tech and protected cultivation methods, and strengthening value chains will be critical to ensuring long-term viability. India's strong position in global floriculture-accounting for 35% of the cultivation area-reinforces the need for strategic investments in technology, research and market linkages. As global flower consumption continues to grow, India has a unique opportunity to lead in sustainable ornamental horticulture while driving inclusive rural development and economic empowerment.

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Artificial Intelligence in Horticulture: A Smart Support System for Vegetable Farmers

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Introduction

Vegetable farming is getting tougher every year. We are seeing a lot of changes in the weather like rain and higher temperatures. There are also pests that are attacking the crops and the cost of farming is going up. In parts of Uttar Pradesh if a farmer makes a small mistake with watering or taking care of diseases it can really hurt the crop.

That is where Artificial Intelligence comes in. Artificial Intelligence is a technology that can help farmers make decisions. It uses information from the weather the soil and the crops to give farmers advice. Artificial Intelligence does not replace the farmer. Instead it helps the farmer by using tools like apps, sensors, cameras, drones and smart machines that collect information from the field in real time.

Why Artificial Intelligence is Useful in Vegetable Farming

Crops like tomatoes, chillies, cabbage and cucumbers need to be taken care of carefully. They need the amount of water, nutrients and protection from diseases. Artificial Intelligence can help farmers by finding diseases telling them when to water, predicting when pests will come and estimating how much crop they will get. This means that farmers can use their resources better and get a yield.

Practical Applications in Horticulture

1. Finding Diseases with Mobile Apps: A farmer can take a picture of a leaf with a smartphone. The Artificial Intelligence system looks at the picture. Compares it to other pictures of diseases. Then it tells the farmer what might be wrong and how to fix it.

2. Smart Watering Systems: Sensors in the

soil tell the Artificial Intelligence software when the crop needs water. This can save a lot of water in fields that use drip irrigation. It can also help the fertilizer work better.

3. Weather Advice: Artificial Intelligence looks at the weather data. Sends warnings to farmers about heavy rain, heat and diseases.

4. Sorting and Grading: Machines that use Artificial Intelligence can sort vegetables by size, color and quality. This makes them more valuable when they are sold.

Artificial Intelligence in Vegetable Research and Breeding

Artificial Intelligence helps scientists study how plants grow pick the varieties and develop crops that can handle different weather conditions. This makes vegetable farming stronger in the run.

Challenges in Adoption

There are some challenges to using



Artificial Intelligence in farming. It can be expensive to set up. Some farmers do not know about it. They also need training to use the technology and internet access can be a problem in areas.. With the right training and support from the government these problems can be solved.

Future Prospects

India is moving towards using technology in farming. In the coming years Artificial Intelligence can help build farming systems that can handle climate change use water carefully and make farming more efficient.

Key Takeaways for Farmers

- Artificial Intelligence helps find diseases
- It saves water and fertilizers

- It reduces the misuse of pesticides
- It improves the yield and quality of crops
- It helps with market planning

Artificial Intelligence is not meant to replace the knowledge of farmers. It is a tool that helps farmers make decisions by using science and technology.

Conclusion

Artificial Intelligence has the potential to change horticulture by making farming more efficient, precise and sustainable. If farmers are aware of the benefits and start using Artificial Intelligence it can become an important partner, in building a stronger and more resilient farming future. Artificial Intelligence and vegetable farming can work together to make farming better.





Vectors used in Genetic Engineering

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Introduction

Vector: it is a substance, usually a piece of DNA that carries a sequence of DNA or other genetic material and introduces it into a new cell.

Genetic engineering has revolutionized biology, medicine and agriculture by enabling the manipulation of genes and the creation of genetically modified organisms. At the heart of most genetic engineering techniques are vectors, which are vehicles used to introduce foreign genetic material into cells. Among the various types of vectors, expression vectors hold particular importance in research and therapeutic applications. Vectors act as vehicles to transfer genetic material from one cell to the other for multiplying, expressing or isolation. Vectors are used as a tool in molecular cloning procedures so as to introduce the desired DNA insert into a host cell. The DNA insert that is transmitted by a vector is termed recombinant DNA, and the process is also known as recombinant DNA technology. Vectors are an important component of the genetic engineering process as these helps for the transfer of gene of interest from one cell to another. The vectors enter the host cell and get incorporated into the host DNA, otherwise just pass the genetic material into the host cell.

Characteristics of vectors

- They should be capable of replicating autonomously.
- They should have sequences that allow the production of proteins essential for the inserted DNA, regulation of the process and further transfer of the insert between different vectors.
- The size of an ideal vector should also be small enough to be incorporated into the host genome.
- They should be easy to isolate and purify as these need to be recovered.
- They should have certain components that facilitate identification of gene transformation.
- They should provide resistance to an antibiotic or produce a particular type of protein.
- These components are called marker genes.
- They should have unique restriction enzyme recognition sites which enable the insertion of the vector DNA in the presence of specific restriction enzymes.
- it is important that the vector should be capable of integrating recombinant DNA into the genome of the host cell.

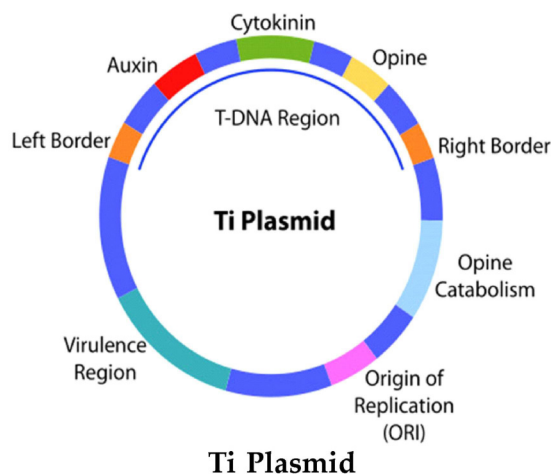
a. Plasmid vector

- Plasmids are small extrachromosomal



circular DNA molecules capable of replicating autonomously within the host cell.

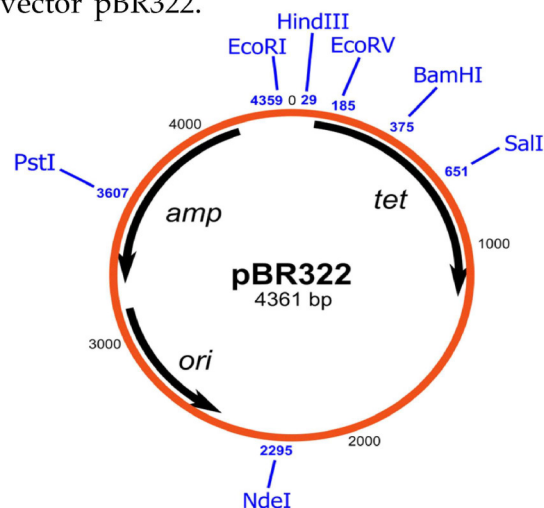
- These are usually utilised in recombinant DNA technology.
- Plasmids are widely used as vectors in all three domains of life.
- The most important feature of plasmids vectors is their small size.
- The size of plasmids ranges from a few thousand base pairs to more than 100 kilobases.
- Plasmids can carry insert DNA that is less than 20 kb as the cloning efficiency.
- The autonomous replication of plasmid is essential feature and independent of the host's replication cycle.
- Bacterial plasmids contain ori sequences that control plasmid replication and determine the possibility of two plasmids coexisting within the same host cell.
- Plasmids have different types of selective markers, including antibiotic resistance and the production of the β -galactosidase enzyme.
- The plasmid used in recombinant DNA technology are pBR322, pUC, and pBluescript vectors that use *E. coli* as the host.



b. Cosmid

- Cosmid vectors are hybrid vectors composed of plasmid and phage vectors.

- They are capable of incorporating up to 42 kb of DNA.
- They are developed by the insertion of the cos region of the phage vector into the plasmid vectors.
- They are large-sized vectors with sizes ranging from 400 base pairs to 30 kb.
- These can carry DNA sequences having sizes ranging from 28 to 46 kb.
- These are hybrid vectors, these can replicate within the host cell like plasmids or remain packaged like a phage.
- The use of cosmid vectors have increased over the years as they are highly efficient and selective for the recovery of larger hybrids.
- One of the examples of the cosmid vectors prepared and used is cosmid pHC79 which is a cos-containing derivative of the vector pBR322.

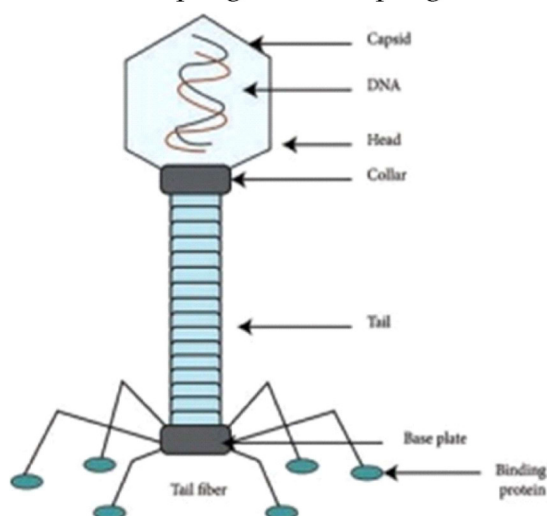


c. Bacteriophage vector

- Bacteriophage vectors are viruses that only infect bacteria.
- Bacteriophages have higher transformation efficiencies recovering a clone containing the recombinant DNA segments.
- The most important feature is the packaging system which enables the incorporation of large eukaryotic genes.
- They facilitate the isolation of larger quantities of DNA molecules.



- The phage λ is the most convenient cloning vector.
- It can package a chromosome about 50 kb in length.
- Phage vectors are effective as cloning vectors as the recombinant molecules formed after the cloning process are packaged into infective particles that can then be stored and handle efficiently.
- Some of the commonly used phages as vectors are λ phages and P1 phages.



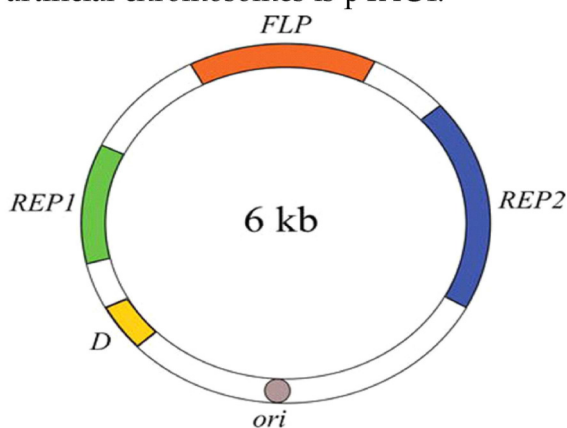
d. Bacterial artificial chromosome

- They are engineered DNA molecules that are used to clone DNA segments in bacterial cells (usually *E. coli*).
- These consist of a bacteria-derived F-factor replication origin which enables the propagation of large DNA fragment.
- They can carry a much larger size of insert DNA as compared to plasmid or phage vectors.
- These vectors are considered superior over other artificial chromosomes like yeast artificial chromosomes.
- These are highly efficient as DNA segments with 300,000 base pairs can be inserted into bacterial artificial chromosomes, which decreases the number of clones and cycles to be performed to obtain the desired result.

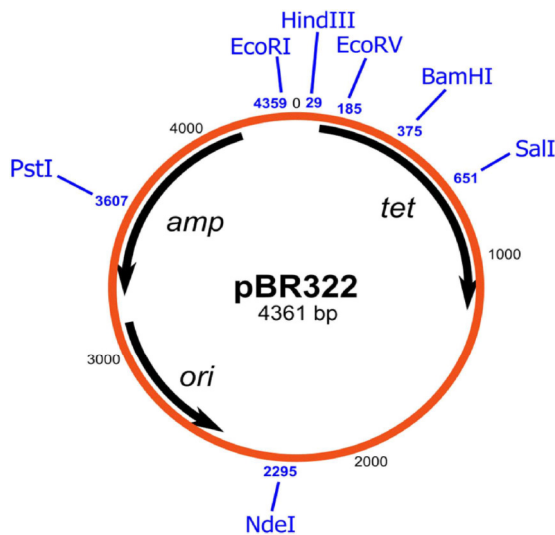
- Their cloning system has been increasingly used in genetic engineering due to its stability and ease of use as compared to other similar vectors.
- They insert the DNA fragments at random into the host genome resulting in unpredicted expression.

e. Yeast artificial chromosome

- They are DNA molecules that are used to clone DNA inserts within the yeast cells, particularly *Saccharomyces cerevisiae*.
- They are developed to clone large sequences of DNA so as to increase the efficiency of the process.
- They can clone up to 500 kb of DNA fragments, which is higher than most traditional cloning vectors.
- Even though these are frequently used as cloning vectors.
- These have unique ability to clone the complete sequences of larger genomes that exceed the limits of traditional techniques.
- Since yeast cells are eukaryotic they can be used for unstable sequences when cloned in prokaryotic systems.
- They insert DNA is cloned, these can function as normally replicating yeast chromosomes.
- They have high degree of chimerism and insert rearrangement.
- One of the most commonly used yeast artificial chromosomes is pYAC4.



f. pBR322



pBR322 (Vector)

- pBR322 is a commonly used plasmid cloning vector used in prokaryotes, primarily *E. coli*.
- The vector consists of an origin of replication from a ColE1-like plasmid, pMB1, an Ap^R gene (Ampicillin resistance gene) from the transposon, Tn3, and a Tc^R gene from pSC101.
- The structure of pBR322 was designed to maximize the number of restriction enzyme cleavage sites on the vector and to minimize its size.
- The vector contains twenty-one unique restriction enzyme cleavage sites.
- The structure also facilitates a unique EcoRI cleavage site within the plasmid in order to increase the efficiency of the vector.
- The pBR322 family of vectors was created for general cloning purposes in *E. coli*.

Application of vectors

- They are used for the transfer of foreign DNA into host cells for different purposes.
- To develop genetically engineered organisms for a particular function, like engineering *E. coli* bacteria for insulin production.
- They can be used to isolate a particular gene sequence within a genome.

- They help determine control sequences and regulatory sequences in genomes for their study and analysis.
- They can be used for studying the structure, function and production of protein in different organisms.
- They can be used to identify mutations in different regions of DNA sequences as well as to diagnose gene defects related to certain diseases.
- They are one of the components in molecular biology which enable numerous studies related to cell structure, nucleic acid composition and genetic engineering techniques.

Limitations of vectors

- They are not stable due to changes in metabolic energy and changing pH and temperature in different hosts.
- Overexpression of a particular type of genes in the host cell is a common problem with the use of vectors.
- The use of a single type of vector may not be sufficient for a particular purpose.
- The use of multiple vectors is complex and results in difficulties.
- Even though a large number of studies are done in the field of molecular biology for the production of more efficient vectors, it is a time-consuming and expensive process.

Conclusion

Expression vectors are a milestone of modern biotechnology. By understanding the components and uses of expression vectors, we can optimize their design and application for a wide range of projects. From Bt protein production in cotton plants to gene therapy, the versatility and expression powers have made them indispensable tools in advancing biotechnological innovations.

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Hybrid Vegetable Seed Production: Principles, Techniques and Prospects in India

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Introduction

Hybrid vegetable seed production has emerged as a crucial technology for enhancing productivity, uniformity, and quality in vegetable crops. Hybrid seeds are produced by crossing two genetically diverse parental lines to exploit heterosis (hybrid vigor), which results in superior yield, improved resistance to pests and diseases, and enhanced adaptability compared to open-pollinated varieties. In India, the demand for hybrid vegetable seeds has increased significantly due to the expansion of commercial vegetable cultivation, rising urban demand, and the need for higher productivity from limited land resources. Hybrid seeds are widely used in crops such as tomato, brinjal, chilli, cabbage, cauliflower, cucurbits, and okra. The Indian hybrid seed industry has grown rapidly with contributions from both public institutions and private seed companies (Kumar et al., 2020).

Hybrid seed production is a specialized and skill-intensive process that requires strict maintenance of genetic purity, controlled pollination, and proper isolation. The success of hybrid seed production depends on the use of stable parental lines, synchronization of flowering, effective pollination techniques, and rigorous quality control measures (Rai & Pandey, 2021).

Concept and Importance of Hybrid Seeds

Hybrid seeds are obtained from the deliberate crossing of two genetically distinct inbred lines known as male and female parents. The first generation (F_1) expresses heterosis, which leads to increased vigor, uniformity and higher yield potential. In

vegetable crops, hybrid varieties often exhibit advantages such as early maturity, improved fruit size and shape, tolerance to abiotic stresses, and resistance to major diseases.

In India, hybrid vegetables have contributed significantly to increased productivity in crops like tomato, capsicum, and cucumber. Studies have reported yield



advantages ranging from 20–50% over open-pollinated varieties, making hybrids highly attractive for commercial growers (Singh *et al.*, 2022).



Genetic Principles of Hybrid Seed Production

Hybrid seed production is based on several genetic and breeding principles:

- 1. Heterosis (Hybrid Vigor):** Superiority of F_1 hybrids over parents.
- 2. Combining Ability:** The ability of parental lines to produce superior hybrids.
- 3. Inbreeding and Development of Parental Lines:** Stabilization of desirable traits through repeated self-pollination.
- 4. Male Sterility Systems:** Used to avoid manual emasculation and facilitate large-scale hybrid seed production.

Male sterility systems widely used in vegetable crops include genetic male sterility (GMS), cytoplasmic male sterility (CMS)

and cytoplasmic-genetic male sterility (CGMS). CMS systems are particularly important in crops such as cabbage, cauliflower, onion and carrot (Yadav *et al.*, 2023).

Methods of Hybrid Seed Production

Hybrid seed production methods vary depending on the reproductive biology of crops. Major methods include:

1. Hand Emasculation and Pollination

This method is commonly used in self-pollinated crops such as tomato, brinjal, and chilli. In this technique, anthers are removed from the female parent before pollen release, and pollen from the selected male parent is transferred manually to the stigma. Although labor-intensive, this method ensures high genetic purity (Sharma & Kaur, 2020).

2. Use of Male Sterility

Male sterility eliminates the need for emasculation. In CMS-based hybrid production, the female parent is male sterile and cannot produce viable pollen, while the male parent provides pollen for fertilization. This method is widely used in cole crops and onion (Kumar & Singh, 2021).

3. Self-Incompatibility System

Self-incompatibility prevents self-fertilization and promotes cross-pollination. Sporophytic self incompatibility system is used in crops like cabbage and cauliflower for hybrid seed production (Rai & Pandey, 2021).

4. Chemical Hybridizing Agents

Certain chemicals (MH, Sodium Methyl Arsenate, FW-450 and Dalapon) can temporarily induce male sterility in plants, facilitating hybrid seed production without genetic male sterility lines. However, their practical application is limited due to environmental and regulatory concerns.

Field Layout and Isolation Requirements

Maintaining genetic purity is essential in hybrid seed production. Proper isolation



distance must be maintained to prevent contamination from other varieties. Isolation distances vary depending on pollination behavior:

- **Self-pollinated crops:** 50–200 m
- **Often cross-pollinated crops:** 400–800m
- **Highly cross-pollinated crops:** up to 1000 m

Field layout generally follows a male-to-female row ratio, such as 1:3 or 1:4, depending on the crop and pollen production capacity of the male parent (Singh *et al.*, 2022).

Pollination Management

Efficient pollination is crucial for achieving high hybrid seed yield. In insect-pollinated crops such as cucurbits, natural pollinators like bees play a vital role. Sometimes managed pollination using honeybee colonies is adopted to improve pollination efficiency. In manual pollination systems, workers transfer pollen from male flowers to female flowers during the early morning hours to ensure successful fertilization (Yadav *et al.*, 2023).

Roguing and Quality Control

Roguing is the removal of off-type plants to maintain genetic purity. It is conducted at different growth stages including vegetative, flowering, and fruiting stages. Seed certification agencies in India follow strict guidelines to ensure hybrid seed quality. After harvest, seeds are processed, graded and tested for germination, purity, and moisture content before marketing.

Challenges in Hybrid Vegetable Seed Production

Despite its advantages, hybrid seed production faces several challenges:

- High labor requirement for manual pollination
- Environmental sensitivity affecting flowering synchronization

- Genetic instability of parental lines
 - Limited availability of male sterility systems in some crops
 - High cost of hybrid seeds for small farmers
- Climate change has also emerged as a major factor influencing seed production environments and pollination efficiency (Kumar *et al.*, 2020).

Future Prospects

Advancements in biotechnology and molecular breeding are transforming hybrid seed production. Techniques such as marker-assisted selection, genomic selection, and CRISPR-based genome editing are helping breeders develop improved parental lines with greater efficiency. Molecular markers are also used to verify hybrid purity at early stages, reducing the risk of contamination. India has significant potential to expand hybrid vegetable seed production due to favorable climatic conditions and skilled labor. Strengthening public–private partnerships, improving seed certification systems, and promoting advanced breeding technologies will further enhance the hybrid seed sector.

Conclusion

Hybrid vegetable seed production plays a vital role in improving vegetable productivity, quality, and profitability. By exploiting heterosis and combining desirable traits from different parental lines, hybrid varieties provide substantial advantages over conventional varieties. Successful hybrid seed production requires precise breeding techniques, proper field management, controlled pollination, and stringent quality control. With the integration of modern breeding technologies and supportive policies, hybrid vegetable seed production will continue to contribute significantly to sustainable vegetable production and food security in India.



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Sustainable Backyard Poultry Production for Livelihood and Family Resource

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Introduction

Keeping poultry makes a substantial contribution to household food security throughout the developing world. It helps in diversify incomes and provides quality food, energy, fertilizer and a renewable asset in over 80 percent of rural households. Family poultry is defined as small-scale poultry keeping by households using family labour and, wherever possible, locally available feed resources. The poultry may range freely in the household compound and find much of their own food, getting supplementary amounts from the householder. All species of poultry are used by rural smallholders throughout the world. The most important species in the tropics are: chickens, guinea fowl, ducks (including Muscovy ducks), pigeons, turkeys and geese. Local strains are used, but most species are not indigenous. The guinea fowl (*Numididae*) originated in West Africa; the Muscovy duck (*Cairina moschata*) in South America; pigeons (*Columba livea*) in Europe; turkeys (*Meleagrididae*) in Latin America; pheasants (*Phasianidae*) in Asia; the common duck (*Anas*) in Europe; and geese (*Anser*) in Asia. Backyard chickens are primarily kept for egg and meat production on a survival basis in rural areas. The term “backyard” chicken was employed to describe rural birds which were reared on a survival basis, on a small scale by a household. In this type of poultry rearing, usually a few birds (10-12 birds) are kept primarily for family use. The surplus birds and eggs are sold in the village or nearby market and the earned money are utilized for fulfilling other requirements of the household. This is a common practice in the rural area. Keeping in view the very low cost of producing rural poultry, the net return from rural poultry could be several times more than that of birds produced on commercial scale. Contribution of rural poultry to household economy could be further enhanced through genetic improvement of the rural birds, in addition to their feeding, management and health status.

In livestock sector, the poultry production has its own impact and value on the overall livestock market and in the GDP contribution. By enhancing poultry production in the form of eggs and meat production ultimately the per capita requirement of the

protein in the country has been bridged markedly. Poultry production is considered to be one of the most efficient and economical system of production of animal protein. Our poultry production is mostly dependent on exotic commercial lines but



still our indigenous poultry at small scale level contribute 30% (about 70 billion) share to our national production of eggs and handsome percentage of share to meat production. Only the need is to improve our indigenous poultry breeds because the Indigenous chickens have the advantage of being well adapted to the local environmental conditions (hot, cold, humid, dry and rainy weather) and can live as a scavenger bird and are reared at a low cost. As the conventional system is going on the women keep the local breed in backyard poultry rearing system and sale eggs in the village and earn money for them.

Interventions for women empowering is, instead of rearing the pure indigenous breed that lays not more the 70-80 eggs per year, why one should not keep the newly developed high egg producing crossbred chicken (Vanaraja, Gramapriya, Narmadanidhi, Giriraja, CARI-Nirbhik, CARI-Shyama, Upcari and Hitkari etc.) that can lay 170- 180 eggs or even more in a year in the same backyard poultry rearing system. Only 25% commercial feed may be supplied to chicks up to 6 months and remaining feeding may be done by kitchen waste and by leaving the birds as a scavenger.

Strategic Features of Backyard Poultry Production In Indian

Poultry System

Advantages of Rural Poultry Production:

Eggs are a high protein, nutritious food with very little waste. When properly managed 10 hens may produce 2000 eggs/year means 40 eggs /week which is 2kg of eggs at a cost of less than Rs 120/dozen or Rs 180/kg. As a bonus, they generate more than 100kg per year of good quality organic fertilizer (poultry manure). Other advantages include:

- The satisfaction of producing something for yourself,
- Independence/self sufficiency,
- Recycling of household scraps – poultry

are good scavengers,

- Supplementary family income
- Assured nutritional support
- Conservation of superior germplasm etc.
- It works as ATM for the family

Structure of Family Poultry By Seasons (Percent)

The average chicken egg production per family was found to be the highest during January-March (20.6) and the lowest (16.4) during July-September in the year. In case of ducks, it was highest (21.1) and lowest (9.4) in the same season. The annual egg production per bird was 37.7 in chickens and 49.7 in ducks. This was highest in both the species during January-March (17.7 in ducks and 10.2 in chickens). It was observed that the total, egg production per bird was higher in ducks than in chickens, indicating that the production potentiality of indigenous ducks was better than that of indigenous chickens.

Socio-Nutritional Support to the Farm Family

Family poultry sector play a crucial role in reduction of malnutrition in children and physical debility in adults, the empowerment of rural women and the conservation of indigenous chicken genetic resources. Poultry provide a major income-generating activity from the sale of birds and eggs. Occasional consumption provides a valuable source of protein in the diet. Poultry also play an important socio-cultural role in many societies. Poultry keeping uses family labour, and women (who often own as well as look after the family flock) are major beneficiaries. Women often have an important role in the development of family poultry production.

Strategies for Breed Improvement

The following two rules should be incorporated into breeding strategies:

- Germplasm in traditional conditions



should not be modified until management and housing have been improved and, even then, selection should be restricted to local breeds.

- When technical conditions are optimum and a ready market exists for the products, then improved breeds, crosses and hybrid strains that have been selected for high performance can be introduced into the peri-urban system, even at small-scale levels.

The most common method of improving the local gene pool is crossing indigenous and exotic birds, and then leaving the hybrid offspring to natural selection. Pure-bred or hybrid cockerels (or pullets) selected for greater meat or egg production is introduced into local flocks, usually in order to increase egg production. It is important to note that improved growth (for meat production) and high egg production are genetically incompatible in the same bird. The genetic traits are negatively correlated, which means that selection for one trait will reduce the other.

Marketing Pattern of Rural Poultry Products

1. Potential target market: The target market is everyone in that rural area or that particular place. People love to eat desi cockerel in the villages so it can be sold at a very high and good remunerative price. When the production quantity and programme increases, the supply of cockerels and eggs can be expanded to the nearest cities and around market.

2. Ceremonial and traditional aspects: In traditional societies, poultry are often used for ceremonies, sacrifices and gifts. Among the Mossi people of Burkina Faso (West Africa), when no poultry is available (such as after a Newcastle Disease outbreak), to meet customary family obligations, the household must purchase or borrow a bird. Chickens are given to convey value to a relationship, or to offer thanks for a

favour or help (such as from government officials). For most socio-cultural and religious purposes, the required sex and colour of fowls are also prescribed. For example, a family will give a white cockerel when an agreement for marriage is reached. A red cock is sacrificed to ask for rain or a good harvest; a white cock is used to convey value in relationships, and a black cock is used to ask for protection against disease, war or quarrels. Because of these customs, red, white and black cocks have double the value of cocks of other colours. To give a gift is considered to be a wealth-increasing action as well as an act that conveys value on the receiver. Farmers often save for agricultural equipment or other materials and small livestock is used as a savings account. The offspring, like chicks, are considered to be the interest on the savings.

3. Spiritual Faith Market: In India especially tribal areas of Bihar, Jharkhand, U.P., M.P. and Odisha, the village "Baiga's" (spiritual leaders) are often using chickens to scarify for removal of ghosts. A frizzle type or coloured birds are preferred which always are very costly and very difficult to get in nearby villages or market.

4. Traditional taste values placed on poultry meat: It is important to understand traditional taste values and their effect on market demand. The market price for free-range birds for meat is usually stable because:

- The meat is considered tastier and stronger flavoured than commercial broiler meat;
- The meat (muscle tissue) is tougher, and retains its texture when prepared in dishes requiring longer cooking; and
- The birds are not fed with compounded feed which may contain antibiotics, anti-mould compounds, enzymes, sulphadiazine and other medicines or synthetic chemicals.

5. Carcass parts and organs market



value: The value of birds for sale in developing countries depends firstly on the available supply, secondly on the age and sex of the birds, and thirdly on their size or weight. Young birds, especially cockerels up to six months of age (weighing up to one kilogram live weight), are usually preferred by consumers. This is because larger birds are more expensive for most households, and smaller birds are tenderer and have the same preferred portions (drumsticks for example).

6. Market supply mechanisms for poultry meat and eggs: Depending on the location of the farm dwelling, birds and eggs are sold from the household to traders (dealers or middlemen), direct to consumers, or carried by the farmer to the local market. The role of traders in the marketing of poultry products is an important one. Traders from urban areas buy eggs in villages to sell in cities. Where transport is an important consideration, guinea fowl eggs, with their stronger shells, are preferred to chicken eggs. Prices of eggs are related to supply and demand, to the higher risk of spoilage and lower use for hatching in hot and humid seasons, and to the availability of alternative protein foods such as fish. There is a tendency to hatch less in the hot season, due to low hatchability and diseases of young chickens, and there is also less hatching in the cold season, due to the risk of chilling stress to the young chicks.

Birds are either brought to the local market once or twice a week for sale to local consumers, to other local markets, or to local traders. Chickens are transported to the market in open-weave (well ventilated) baskets or wooden crates. The price of live birds depends on their size, the price of eggs depends more on number.

Constraints

Small-scale producers are however constrained by poor access to markets, goods and services; they have weak

institutions and lack skills, knowledge and appropriate technologies. The result is that both production and productivity remain well below potential and losses and wastage can be high. However, adapted breeds, local feed resources and appropriate vaccines are available, along with proven technologies that can substantially improve productivity and income generation.

The low success rate of ND vaccination is almost entirely due to inactivation of the vaccine because of the absence of an efficient cold chain. This in turn is aggravated by the scattered distribution of village flocks, bad road conditions and lack of transport. Vaccination programmes should be carried out at appropriate times. There are seasonal patterns to outbreaks of ND and Fowl Pox, the diseases for which vaccination campaigns are usually carried out. It has frequently been said that lack of motivation is a major cause of the low vaccination rates in rural areas.

Technology Transfer Approach

Transfer of technology should include a communication strategy for Small holder/ rural poultry Production for a Food. A strategy is a systematic process which takes into account the objectives, the results to be achieved and the technical activities to be carried out. In a participatory planning strategy, it is necessary to identify the needs of the stakeholders and target groups, in order to:

- Determine shared values, knowledge and the advantages of the project to be implemented;
- Identify the strengths and weaknesses of the topics to be disseminated and identify appropriate tools /media and methodologies;
- Assess the constraints (such as limited resources) which are likely to limit the range of alternative actions;
- Assess opportunities and threats;



- Consider all alternative proposals given to achieve the objectives;
- Select the plan which appears to have the greatest chance of achieving the objectives;
- Implement the plan and its activities; and
- Periodically monitor, evaluate and revise the plan /activities.

A good extension methodology should include a systematic, rational and pragmatic approach to planning, implementing, managing, monitoring, and evaluating effective technology transfer to the farmers.

Capacity-building

Organization of support services and input supply is a critical element of any model that attempts to link smallholders with output markets. This requires support from people with strong organizational skills. Thus, appropriate capacity-building measures must become an integral part of interventions that design and implement live-lihood-support options such as backyard poultry. Successful projects such as those implemented by BRAC and Kegg farms can be a resource for this training. Similarly, government and NGOs can provide technical training.

Linking With Microcredit

Microfinance organizations and self-help groups may help with credit to finance

important expenditures. Establishment of strong linkages with micro-credit organizations is must, therefore, be seen as an integral component of all livelihood-support interventions, including household poultry. Besides facilitating access to credit, credible microcredit organizations and self-help groups can also help by rationalize interest rates.

Conclusion

In India, Poultry has been playing a vital role in bridging the gap between supply and requirement of animal protein food of high biological value. Our indigenous poultry possesses bright prospects for future development in view of easy and abundant availability of all the requisite inputs such as land, labor and feed resources in rural areas and lower cost of production as compared to commercial poultry. Backyard poultry provides recreation, employments, women empowerments, germplasm conservation, women's pocket money, family peace and amity harmony in the family, time utilization, technical and monetary contribution to the nation and family nutrition. Backyard poultry may contribute at large in national egg, meat and farmyard manure production and rural employment at minimum expenses.

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Recent Trends in Fruit Crops Cultivation: Technological, Genomic, and Sustainable Approaches for Climate-Resilient Horticulture

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Introduction

Fruit crops play a critical role in ensuring global nutritional security, livelihood generation, and agricultural diversification, particularly in developing economies where horticulture provides higher income per unit area than cereal-based systems. Fruits are rich sources of vitamins, minerals, dietary fibre, antioxidants, and bioactive compounds, contributing significantly to the prevention of malnutrition and lifestyle-related diseases. In India, fruit production has shown a steady upward trend, increasing from 86.6 million tonnes in 2014–15 to 112.97 million tonnes in 2023–24, with mango, banana, citrus, and guava accounting for a major share of total output. This expansion reflects increasing domestic demand, improved production technologies, and the growing importance of horticulture in enhancing farmers' income and export earnings.

Despite this progress, fruit production systems are increasingly challenged by multiple biotic and abiotic constraints. Climate change-induced stresses such as rising mean temperatures, erratic rainfall, prolonged droughts, and an increased frequency of heatwaves have significantly altered phenology, fruit set, and yield stability. Abiotic stresses alone are estimated to reduce fruit yields by up to 30%, while their interaction with emerging pests and diseases further exacerbates production losses. Additionally, declining soil health, nutrient imbalances, and inefficient resource use threaten the long-term sustainability of orchard ecosystems. Postharvest losses remain a critical bottleneck, often accounting for 30–50% of total production due to inadequate storage, transportation, and handling infrastructure, particularly in tropical and subtropical regions.

Under these rapidly changing conditions, traditional orchard management practices, which are largely input-intensive and climate-insensitive, are proving increasingly inadequate. Consequently, there is a growing need to adopt innovative,

knowledge-driven, and technology-enabled approaches that enhance productivity while minimizing environmental impacts. In this context, the present review critically synthesizes recent advances and emerging trends in fruit crop cultivation, including



genomic interventions, precision horticulture, intensive planting systems, regenerative management practices, and postharvest innovations. Emphasis is placed on evaluating their potential contributions to developing sustainable, resource-efficient, and climate-resilient horticultural systems capable of meeting future food and nutritional demands.

Genomic Innovations in Fruit Crop Breeding

Genome editing technologies, particularly CRISPR/Cas systems, have emerged as powerful tools for precision breeding in fruit crops characterized by long juvenile phases and complex genomes. Unlike conventional breeding, CRISPR/Cas-mediated editing enables targeted, non-transgenic modifications that accelerate cultivar development.

Recent studies have demonstrated successful editing of *DIPM* genes in apple for fire blight resistance and *CsLOB1* promoter regions in citrus to confer resistance against citrus canker, resulting in a 50–70% reduction in fungicide use.

Multiplex genome editing has facilitated the simultaneous improvement of multiple traits, including disease resistance, fruit quality, and shelf life, in crops such as tomato, banana, grape, strawberry, mango, and kiwifruit. Emerging base and prime editing technologies further enhance precision, enabling fine-tuning of traits related to flavour, firmness, and nutritional quality. Regulatory advancements in countries such as India and the European Union are increasingly favouring genome-edited crops, thereby accelerating their commercialization and adoption.

Table 1. Genome editing targets and applications in fruit crops

Crop	Target Gene(s)	Edited Trait
Apple	DIPM-1/2/4	Fire blight resistance
Citrus	CsLOB1 promoter	Citrus canker resistance
Tomato	PSY1, MYB12	Color enhancement, GABA boost
Grape	VvMLO7, WRKY52	Powdery/grey mold resistance
Banana	BSV ORF	Streak virus resistance

Precision Agriculture and Digital Technologies

Precision horticulture has revolutionized orchard management by enabling real-time, site-specific decision-making. The integration of IoT-based soil and climate sensors, GPS-enabled machinery, hyperspectral imaging, and AI-driven analytics allows growers to manage spatial variability within orchards more efficiently. Studies published in *Computers and Electronics in Agriculture* report that drone-based nutrient and stress detection systems achieve up to 95% accuracy, reducing fertilizer and irrigation inputs by 20–30%.

Artificial intelligence and machine learning

models have been increasingly used for yield forecasting, fruit maturity assessment, pest surveillance, and automated harvesting. Variable rate application technologies optimize resource use, while blockchain-enabled traceability enhances market access for premium fruits. In India, pilot programs led by ICAR demonstrate the potential of precision technologies to improve productivity, export quality, and profitability, particularly in mango and apple orchards.

High-Density and Intensive Planting Systems

High-density planting (HDP) and ultra-high-density planting (UHDP) systems have gained prominence as effective



strategies to maximize productivity per unit area. These systems rely on dwarfing rootstocks, optimized spacing, canopy management, and fertigation to achieve early and higher yields. Research indicates that HDP systems can increase yields by 1.5–2 times, while UHDP systems can achieve two- to threefold yield enhancement within three to four years of planting. Crops such as mango, guava, citrus, apple,

grape, and pomegranate have shown significant performance improvements under intensive planting systems. Although challenges such as higher initial investment and increased management complexity exist, these can be mitigated through mechanization, pruning strategies, and growth regulators. The adoption of intensive planting systems is expanding rapidly in major fruit-growing regions of India.

Table 2. Planting density systems and yield advantages

System	Density (plants/ha)	Yield Gain	Key Crops
HDP	400-1,600	1.5-2x	Mango, guava
UHDP	3,000-5,000	2-3x	Citrus, pomegranate
Meadow	10,000-20,000	3-4x	Apple, peach

Regenerative and Sustainable Orchard Management

Regenerative agriculture has emerged as a promising approach to enhance orchard sustainability by improving soil health, biodiversity, and ecosystem services. Practices such as cover cropping, reduced tillage, compost application, and agroforestry have been shown to increase soil organic carbon by 20–50% and enhance microbial activity. Improved soil structure and water-holding capacity contribute to greater resilience against drought and temperature extremes.

Precision irrigation systems combined with soil moisture sensors have reduced water use by 20–40%, while biofertilizers and organic amendments have lowered chemical fertilizer dependency. Long-term trials indicate that regenerative practices can maintain or increase yields while significantly reducing environmental impacts, aligning well with national and global sustainability goals.

Advances in Postharvest Management

Postharvest losses remain a major challenge in fruit supply chains, particularly in

tropical and subtropical regions. Recent advances in postharvest technologies, including edible coatings, non-thermal treatments, and smart packaging, have shown substantial potential to reduce losses and extend shelf life. Chitosan- and alginate-based edible coatings have extended the shelf life of fruits such as mango, banana, and berries by up to 50%, while maintaining firmness and nutritional quality.

Non-thermal technologies such as UV-C irradiation, ozone treatment, cold plasma, and pulsed electric fields effectively inactivate pathogens without compromising fruit quality. Smart packaging systems equipped with RFID and gas sensors enable real-time monitoring of fruit quality during storage and transportation. Additionally, valorization of fruit processing waste through the extraction of bioactive compounds contributes to circular economy approaches in horticulture.

Future Perspectives and Research Gaps

Despite significant technological advancements, large-scale adoption of modern fruit production technologies remains constrained by high costs, limited technical capacity, and regulatory uncertainties. Future



research should focus on long-term, field-based validation of integrated production systems combining genomics, precision agriculture, intensive planting, and regenerative practices. Policy support, capacity building, and public-private partnerships will be essential to ensure equitable access to these innovations, particularly for smallholder farmers.

Conclusion

The evolution of fruit crop cultivation is marked by a decisive shift toward intelligent, sustainable, and climate-resilient production systems. Genomic innovations,

precision horticulture, intensive planting systems, regenerative management, and advanced postharvest technologies collectively address key challenges facing modern fruit production. Strategic integration of these approaches has the potential to enhance productivity, resource-use efficiency, fruit quality, and environmental sustainability. This review highlights the need for interdisciplinary research and supportive policy frameworks to facilitate widespread adoption and ensure the long-term sustainability of global fruit production systems.





Banana Mild Mosaic Virus: A Silent Threat to Banana Cultivation

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Introduction

Bananas (*Musa* spp.) are among the world's most important fruit crops, serving as staple food and a vital source of income for millions of people across tropical and subtropical regions. Despite their economic and nutritional significance, banana production is increasingly threatened by viral diseases. Among these, *Banmivirus musae*, commonly known as banana mild mosaic virus (BanMMV), has emerged as a growing concern due to its silent spread, high molecular diversity, and frequent involvement in mixed viral infections. It was first identified and characterized from Australia in banana plants of cv. Ducasse. BanMMV belongs to the family *Betaflexiviridae* and produces flexuous filamentous particles approximately 580 nm in length, containing a positive-sense single-stranded RNA genome. Genome characterization has revealed a ~7.3kb nucleotide RNA molecule encoding five open reading frames, displaying sequence similarities to members of the genera *Carlavirus*, *Foveavirus*, and *Potexvirus*. However, the virus does not clearly align with any recognized genus, underscoring its unique taxonomic position and the challenges associated with its detection and classification.

Global Distribution and Economic Importance

BanMMV is now recognized as one of the most widely distributed viruses infecting *Musa* spp., with confirmed presence in germplasm collections and field plantations across Asia, Africa, Latin America, Oceania, and the Caribbean. Its global spread is largely facilitated by the movement of infected planting material, especially tissue-culture plantlets and suckers, as infections are often latent and escape visual detection during routine screening. Although the direct economic impact of BanMMV alone remains modest and has not been fully quantified, its significance increases

substantially in mixed infections. Co-infection with other major banana viruses—such as banana streak virus (BSV), banana bract mosaic virus (BBrMV), and Cucumber mosaic virus (CMV) can result in severe leaf necrosis, intensified chlorosis, stunting, and reduced plant vigor. The combination of its widespread distribution, predominantly asymptomatic infections, and challenges in reliable detection makes BanMMV a pathogen of increasing phytosanitary concern. These characteristics allow the virus to circulate silently through vegetative propagation and international germplasm exchange, underscoring the need for robust diagnostic protocols and strengthened management strategies to prevent further



dissemination.

Symptoms

One of the most challenging aspects of BanMMV management is its tendency to cause mild or asymptomatic infections. Many cultivars exhibit no visible symptoms, contributing to unintentional spread through infected suckers and tissue-cultured plants. When symptoms do appear, they may include light chlorotic

streaks, faint mosaic patterns, and fine silvery or continuous/broken leaf streaks (noted especially in cultivars like Pisang Awak) on leaf lamina (Fig 1). Also, transient mosaic symptoms on young leaves, which may disappear as the plant matures. Further, symptom severity increases dramatically under mixed infections, making diagnosis based purely on visual observation unreliable.



Figure 1: Characteristic symptoms of BanMMV infection on banana

Transmission and Spread

BanMMV is primarily transmitted through vegetative propagation, including suckers and *in vitro* plantlets. There is currently no confirmed insect vector, and attempts to transmit the virus mechanically or through known banana vectors such as aphids (*Pentalonia nigronervosa*) and mealybugs (*Planococcus citri*) were unsuccessful. However, studies indicate possible unexplained plant-to-plant transfer in field conditions.

Molecular biology

BanMMV with a genome size of 7.3kb organized into five open reading frames (ORFs) that encode essential viral proteins (Fig 2). ORF1 encodes the RNA-dependent RNA polymerase (RdRp), a key enzyme

required for viral replication. ORFs 2 to 4 encode the triple gene block proteins (TGBp1–TGBp3), which play crucial roles in facilitating cell-to-cell movement of the virus within host tissues. ORF5 encodes the coat protein (CP), which encapsidates the viral RNA and is vital for virion stability and infectivity. BanMMV displays extremely high genetic variability. Analyses of partial RNA-dependent RNA polymerase (RdRp) and coat protein (CP) sequences showed mean nucleotide divergence of about 20% across isolates worldwide. A group of partial CP sequences from Ivory Coast showed even higher diversity (35%). This diversity complicates PCR-based detection because mismatches in primer binding regions can lead to false negatives.



Figure 2: Genome organization of Banana mild mosaic virus



Detection and Diagnosis

Due to its high variability and often asymptomatic nature, BanMMV detection requires sensitive and inclusive molecular tools. Key diagnostic approaches include:

- RT-PCR assays targeting CP or RdRp regions
- Nested PCR using degenerate primers to capture diverse isolates
- Immunocapture RT-PCR (IC-RT-PCR) depending on availability of polyclonal antibodies
- High-throughput sequencing (HTS), which has demonstrated 100% diagnostic sensitivity and specificity in detecting BanMMV from *in vitro* plants

HTS has proven capable of detecting divergent isolates and even discovering new *Betaflexiviridae* species, making it a valuable tool for germplasm health certification. Routine indexing of banana germplasm requires growth of plants for up to six months in greenhouses, combined with PCR and electron microscopy, as part of international phytosanitary protocols such as those recommended in the *MusaNet* Technical Guidelines.

Management

As BanMMV lacks a known vector, management efforts should focus on preventing its introduction through virus-free planting material. Recommended measures include:

- Meristem culture combined with chemotherapy (e.g., ribavirin), proven effective in eliminating BanMMV from infected cultivars such as Pisang Awak and Pisang Seribu
- Strict adherence to international guidelines for the safe movement of *Musa* germplasm
- Regular indexing of mother plants used

in tissue-culture production

- Use of HTS or reliable RT-PCR assays during pre-indexing and certification programs

Conclusion

Banana mild mosaic virus represents a silent but significant phytosanitary challenge in global banana production. Although often mild on its own, BanMMV's high prevalence, genetic diversity, and synergistic interactions with other viruses make it a potential threat that cannot be ignored. With increased global movement of banana germplasm, robust diagnostic protocols, advanced detection technologies, and strict adherence to sanitation guidelines are essential to minimize risks. Strengthening viral indexing programs and implementing improved molecular tools will be crucial to safeguard banana cultivation against this silent threat.

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The Hybrid Revolution: Engineering Nature for a Food-Secure Future

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Introduction

Hybrid seed production is the meticulous art and science of cross-breeding two genetically distinct, yet pure, parent lines to create an offspring (the F1 hybrid) that outperforms both its parents. This isn't random chance; it's a controlled genetic strategy designed to unlock specific, desirable traits. In the realm of vegetable cultivation, this process has moved from an agricultural technique to a strategic imperative, driving productivity, quality, and resilience in the face of climate change and shrinking arable land.

The Importance of Hybrid Seeds in Vegetable Crops

The adoption of hybrid vegetables has transformed modern horticulture. Their significance is multi-faceted:

- **Yield Enhancement:** The primary driver. Hybrids often exhibit a dramatic increase in yield per hectare, a phenomenon crucial for feeding a growing population.
- **Uniformity and Quality:** Unlike open-pollinated varieties, F1 hybrids are remarkably uniform in size, shape, color, and maturity. This is a boon for commercial farming, meeting the stringent standards of modern retail and export markets.
- **Built-in Resilience:** Breeders deliberately incorporate resistance to specific diseases, pests, and environmental stresses (like drought, heat, or soil salinity). This reduces dependency on chemical pesticides and makes farming more sustainable.
- **Extended Harvest Window:** Hybrids can be engineered for specific maturity durations and longer shelf-life, reducing

post-harvest losses and ensuring a steadier supply to the market.

Heterosis (Hybrid Vigor) and Its Advantages

The magic behind hybrid superiority is Heterosis, or "hybrid vigor." It describes the phenomenon where the F1 generation exhibits a level of robustness, size, and productivity that surpasses the best-performing parent.

Why does this happen? The leading theory is the "masking of deleterious recessives." Imagine each parent line has hidden, weak genetic traits (recessive alleles). When crossed, the dominant, healthy genes from one parent cover up the weak genes of the other in the offspring, leading to a overall healthier and more vigorous plant.

Advantages reaped from heterosis include:

- **Faster Vegetative Growth:** Quicker canopy establishment and stronger plant structure.
- **Greater Stress Tolerance:** Enhanced



ability to withstand biotic and abiotic pressures.

- **Improved Physiological Efficiency:** Better nutrient uptake, photosynthesis, and resource utilization.

Global and Indian Market Scenario: A Booming Ecosystem

- Globally, the vegetable seed market is dominated by hybrids, valued at over \$10 billion and growing steadily. Companies like Bayer (following its acquisition of Monsanto), Corteva Agriscience, Syngenta, and BASF lead the innovation charge, investing heavily in R&D for traits like nutrition, flavor, and climate adaptability. The demand is driven by rising health consciousness, urbanization, and the need for high-value vegetables.

- In India, the hybrid vegetable seed market is a powerhouse of growth, valued at over \$700 million. India is not just a massive consumer but also a major production and export hub for hybrid seeds, particularly for crops like tomato, okra, chili, and cucumber. States like Karnataka, Maharashtra, and Gujarat are central to this industry. The success story is fueled by:

- o **Mission-Driven Initiatives:** Government schemes promoting high-value agriculture.
- o **The Rise of Protected Cultivation:** Greenhouses and polyhouses that maximize the potential of high-cost hybrid seeds.
- o **A Strong Network:** A robust partnership between multinational companies, Indian seed firms, and a vast network of contract seed growers.

Types of Hybrid Seed Production Systems

The methodology for creating hybrids is fundamentally dictated by the natural pollination habits of the crop.

Self-Pollinated Crops vs. Cross-Pollinated Crops

- **Self-Pollinated Crops** (e.g., Tomato, Chili, Pepper, Eggplant):

- o **Natural Habit:** Flowers are perfect (contain both male and female parts) and typically self-fertilize.

- o **Hybridization Challenge:** The main challenge is to prevent self-pollination in the female parent line.

- o **Method:** Emasculation and Hand Pollination. This is a labor-intensive but highly precise process.

- **Cross-Pollinated Crops** (e.g., Cucumber, Pumpkin, Corn, Onion, Cabbage):

- o **Natural Habit:** Relies on wind or insects to transfer pollen between plants.

- o **Hybridization Challenge:** The main challenge is to prevent the female parent from receiving pollen from any plant other than the intended male parent.

- o **Methods:** These are more scalable and include Cytoplasmic Male Sterility (CMS) and the use of Gynoecious Lines and Plant Growth Regulators.

Methods of Hybrid Seed Production with Case Studies

Case Study 1: The Labor of Love – Tomato (A Self-Pollinated Crop)

- **Method:** Emasculation and Hand Pollination.

- **Process:**

1. **Female Parent Preparation:** Flower buds on the female parent plants are selected a day before they would naturally open.

2. **Emasculation:** Using fine-tipped forceps, the anther cone (the male part containing pollen) is carefully removed without damaging the pistil (female part).

3. **Pollination:** Over the next 1-2 days, pollen collected from the flowers of the selected male parent is gently applied to the stigma of the emasculated flower.

4. **Tagging:** The pollinated flower is tagged to mark it for future hybrid seed harvest.

- **The "Unique" Angle:** This method is the



foundation of the hybrid industry in regions with access to skilled labor. It's a testament to human precision, where the "field" is more like a surgical theater. The cost of hybrid tomato seed is directly linked to this immense manual effort, often involving thousands of trained workers, predominantly women, during the flowering season.

Case Study 2: The Genetic Masterstroke – Onion (A Cross-Pollinated Crop)

- **Method:** Cytoplasmic Male Sterility (CMS).

- **Process:**

1. **The CMS Line (A-line):** This is the female parent. A natural genetic mutation in its mitochondria makes it produce no viable pollen. It is, effectively, a "male-sterile" plant.

2. **The Maintainer Line (B-line):** This line is genetically identical to the A-line but has normal cytoplasm, so it is fertile and produces pollen. When crossed with the A-line, it maintains the male sterility, producing more A-line seeds.

3. **The Restorer Line (R-line):** This is the male parent. It possesses a restorer gene that counteracts the male sterility. When its pollen is crossed with the A-line, the resulting F1 hybrid is fully fertile and high-yielding.

- CMS is a brilliant biological hack. It eliminates the need for tedious emasculation. In the field, rows of male-sterile (A-line) plants are alternated with rows of the male (R-line) parent. Insects (like honeybees) naturally cross-pollinate them. The entire seed harvest from the A-line plants is the commercial F1 hybrid seed. This method makes large-scale, economical hybrid onion seed production possible.

Case Study 3: The Hormonal Hack – Cucumber (A Cross-Pollinated Crop)

- **Method:** Utilizing Gynoecious Lines & Ethrel.

- **Process:**

1. **Gynoecious Lines:** These are special

female parent lines that produce almost exclusively female flowers.

2. **Inducing Male Flowers:** To maintain the gynoecious line, it is treated with a plant growth regulator like Silver Nitrate or Gibberellic Acid, which induces the formation of male flowers, allowing it to self-pollinate.

3. **Hybrid Production:** For commercial hybrid seed production, the gynoecious line is planted alongside a monoecious male parent (one that has both male and female flowers). To ensure the gynoecious line does not self-pollinate, it is sometimes treated with Ethephon (Ethrel), which suppresses male flower formation entirely. This guarantees that all seeds set on the gynoecious plants are the result of cross-pollination from the designated male parent.

- This method showcases how a deep understanding of plant sexuality and plant hormones can be leveraged for efficient seed production. It allows for nearly 100% hybridity without manual emasculation, making cucumber hybrid seed production highly efficient and reliable.

Conclusion

The hybrid seed industry is not static. The future lies in combining traditional hybrid technology with cutting-edge tools like Marker-Assisted Selection to speed up the development of pure parent lines, and Gene Editing (CRISPR) to introduce precise traits without the lengthy conventional breeding process. While challenges like seed cost and farmer dependency exist, the undeniable benefits of hybrids—in ensuring food security, nutritional quality, and agricultural sustainability—cement their role as a vital pillar of 21st-century agriculture. The hybrid revolution, born in scientific labs and nurtured in carefully managed fields, continues to evolve, promising smarter and more resilient crops for the future.



Ridge Gourd (*Luffa acutangula* L.) as a Functional Vegetable: Nutritional Composition, Phytochemical Properties and Health Benefits

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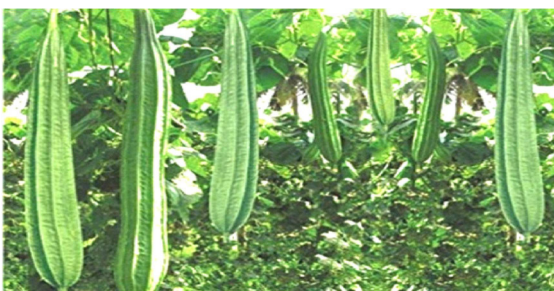
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Introduction

Ridge gourd (*Luffa acutangula* L.), also known as angled luffa, ridged luffa, vegetable gourd or Chinese okra, is an important cucurbitaceous vegetable widely cultivated in tropical and subtropical regions, particularly in India and Southeast Asia. It belongs to the family Cucurbitaceae and is valued both for its culinary and medicinal properties. It is originated in India. Out of nine species seven are found in India. In India, ridge gourd is commonly known as "Turai" or "Tori" and is consumed as a cooked vegetable. Besides its dietary importance, it has been traditionally used in indigenous systems of medicine such as Ayurveda for treating jaundice, diabetes, skin disorders and digestive ailments.

It can be grown in warm hot condition ranging from 25-30°C with neutral to slightly acidic soil condition (pH 5.5-6.5). Some improved variety like *Pusa Nasdar*, *Arka Sujat*, *Arka Sumeet*, *Konkan Harita*, *Phule Suchita*, *Pusa Nutan*, *Swarna Manjari* and *Swarna Uphar* provides maximum yield and profit.



Nutritional Composition of Ridge Gourd

Ridge gourd is a low-calorie vegetable with high moisture content and appreciable amounts of essential nutrients. According to the Indian Food Composition Tables published by the National Institute of

Nutrition (2017), the approximate nutritive value per 100 g of edible portion of ridge gourd is as follows:

Moisture	93-95 g
Energy	17-20 kcal
Carbohydrates	3.4-4.0 g
Protein	0.5-0.7 g
Fat	0.1-0.3 g
Dietary fiber	0.5-1.0 g
Calcium	18-20 mg
Phosphorus	20-25 mg
Iron	0.4-0.5 mg
Vitamin C	10-12 mg
β-carotene	150-200 µg



These values indicate that ridge gourd is primarily a water-rich vegetable with moderate carbohydrate content and minimal fat, making it suitable for low-calorie diets. The presence of vitamin C and β -carotene contributes to its antioxidant potential (Mudambi, 2001).

Macro & Micronutrients

The carbohydrate fraction mainly consists of simple sugars and soluble fibers, which aid in digestion. Though the protein content is relatively low, it contains essential amino acids in small quantities. The fat content is negligible, which supports its inclusion in heart-healthy diets.

Ridge gourd contains essential minerals such as calcium and phosphorus, important for bone health and iron, which contributes to haemoglobin formation. Vitamin C enhances iron absorption and boosts immune function. The β -carotene content acts as a precursor to vitamin A, supporting vision and epithelial health.

Phytochemical Constituents

Beyond its basic nutritional profile, ridge gourd contains numerous bioactive compounds. Phytochemical screening has revealed the presence of:

- Flavonoids
- Phenolic compounds
- Saponins
- Triterpenoids
- Alkaloids
- Tannins

The fruit, seeds and leaves contain cucurbitacin and other triterpenoids that exhibit pharmacological properties. These compounds are responsible for many of the medicinal benefits associated with ridge gourd.

Antioxidant Properties of Ridge Gourd

Oxidative Stress and Antioxidants

Oxidative stress results from an imbalance between reactive oxygen species (ROS) and

antioxidant defences. Excess ROS can damage cellular lipids, proteins and DNA, contributing to chronic diseases such as cancer, diabetes, cardiovascular diseases and neurodegenerative disorders.

Antioxidant Compounds in Ridge Gourd
Ridge gourd exhibits significant antioxidant activity due to:

- **Vitamin C:** A water-soluble antioxidant that scavenges free radicals.
- **β -carotene:** A carotenoid that protects cells from oxidative damage.
- **Flavonoids and Phenolics:** Plant secondary metabolites known for strong radical-scavenging activity.

Methanolic extracts of *Luffa acutangula* fruits show considerable DPPH radical scavenging activity, indicating strong antioxidant potential. The total phenolic content is positively correlated with antioxidant capacity.

Mechanism of Action

Phenolic compounds donate hydrogen atoms or electrons to stabilize free radicals. Flavonoids chelate metal ions and inhibit lipid peroxidation. Vitamin C regenerates other antioxidants such as vitamin E enhancing overall antioxidant defence.

Health Benefits of Ridge Gourd

1. Antidiabetic Activity

Ridge gourd has shown promising hypoglycaemic effects. Extracts of *Luffa acutangula* significantly reduce blood glucose levels. The mechanism may involve enhancement of insulin secretion, improved glucose uptake and inhibition of carbohydrate-digesting enzymes.

2. Hepatoprotective Effect

The fruit and leaf extracts shows hepatoprotective activity against chemically induced liver damage. This protective effect is attributed to antioxidant compounds that reduce lipid peroxidation and restore liver enzyme levels.

3. Anti-inflammatory and Analgesic Effects



Flavonoids and triterpenoids present in ridge gourd possess anti-inflammatory properties by inhibiting inflammatory mediators such as prostaglandins. It reduces inflammation and pain following extract administration.

4. Cardioprotective Benefits

Due to its low fat and cholesterol-free nature, ridge gourd supports cardiovascular health. Dietary fiber helps reduce serum cholesterol levels, while antioxidants prevent oxidative damage to blood vessels.

5. Digestive Health

The high water and fiber content improve bowel movement and prevent constipation. Traditionally, ridge gourd has been used as a mild laxative and digestive aid in Ayurvedic medicine.

6. Skin and Hair Health

Ridge gourd is often recommended in traditional remedies for skin disorders. The presence of antioxidants helps reduce oxidative stress in skin cells, promoting healthier skin. The dried fibrous structure of mature fruits (loofah sponge) is also used as a natural exfoliant.

7. Weight Management

With very low calorie and fat content, ridge gourd is ideal for weight-loss diets. It provides satiety due to its fiber and water content without adding significant calories.

8. Immune Support

Vitamin C enhances immune cell function and resistance against infections. Regular consumption of ridge gourd can contribute to improved immunity.

9. Anticancer Potential

Phenolic compounds and cucurbitacin exhibit cytotoxic effects against certain cancer cell lines. Though research is preliminary, these compounds may contribute to chemo preventive activity.

Traditional and Ethnomedicinal Uses

In Ayurveda, ridge gourd is considered cooling and is used to treat pitta-related

disorders. It is prescribed for jaundice, splenomegaly and skin diseases. The seeds are sometimes used as an anthelmintic. The juice of fresh fruit is traditionally administered in cases of diabetes and liver disorders.

Safety and Considerations

Although ridge gourd is generally safe for consumption, rare cases of toxicity have been reported when bitter-tasting fruits (due to high cucurbitacin content) are consumed. Excessive bitterness may indicate elevated levels of toxic compounds, which can cause gastrointestinal irritation. Therefore, bitter fruits should be avoided.

Conclusion

Ridge gourd (*Luffa acutangula* L.) is a nutritionally valuable vegetable with significant antioxidant potential and multiple health benefits. It is low in calories and rich in moisture, vitamins, minerals and bioactive phytochemicals. Scientific studies support its antidiabetic, hepatoprotective, anti-inflammatory and cardioprotective effects, largely due to its antioxidant constituents such as vitamin C, β -carotene, flavonoids and phenolic compounds. Incorporating ridge gourd into regular diets can contribute to improved health and prevention of chronic diseases.

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Mutation: A Breeding Method for Improvement in Vegetable Crops

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Introduction

In plant breeding, a variety of techniques can be employed to enhance a crop's genetic variability, which is followed by selection processes that look for beneficial genotypes (those exhibiting increased yield, disease resistance, or improved flower color). Cross-breeding is one of the primary techniques used by plant breeders to try to integrate advantageous traits from various sources into a single genotype. Conversely, mutation breeding exploits the potential for gene modification through the application of chemical or physical mutagens to seeds or other plant parts. "Mutation" was first used by Dutch botanist Hugo De Vries (1848–1935). According to him any abrupt, heritable alteration to an organism's DNA that is not caused by regular recombination and segregation is called a mutation. It refers to any modifications made to an organism's DNA that are not brought about by recombination and segregation brought on by hybridization. Mutation breeding is frequently employed to give crops new, desirable features. Its primary goal is to cause a great deal of variety in the population. The degree of genetic variability found in the available germplasm is the basis for choosing superior germplasm. In certain minor vegetable crops, such as leafy (basella, palak, spinach, and amaranth), broccoli, Brussels sprouts, Chinese cabbage, and tubers like elephant foot yam and Chinese potatoes There is very little genetic variability. According to Ashadevi *et al.*, (2017), induced mutagenesis can be effectively used in these situations as a substitute to create variability in many quantitative aspects. Because mutation breeding involves modifying the genetic material of an already-adopted cultivar to make corrections, it also aids in accelerating the development of variations. A limited number of experiments successfully resulted in the release of new varieties in crops such as tomato and okra. Like spontaneous genetic events, these intentionally produced genetic events are diverse and can be classified as either chromosome aberrations (involving a few or many genes) or gene mutations (involving only one gene). The plant breeder is typically more interested in the recessive gene mutations as opposed to chromosome abnormalities, which frequently result in decreased fertility-a major disadvantage for species that are spread by seeds. Chemicals like EMS (ethyl methane-sulphonate) or different forms of ionizing radiation (such as X-rays, neutrons, ultraviolet light, etc.) can cause mutations. Vegetatively propagated crops are an ideal group of plants for the use of mutant breeding techniques for a number of reasons. The main advantage of mutation induction in vegetatively propagated crops is the ability to change one or a few characters of an otherwise out-standing cultivar without altering the remaining and often unique part of the genotype. The sole cause of variation in obligatory apomicts or sterile plants is mutation.



Characteristics of Mutation

Below is a summary of the primary characteristics of mutations:

1. A mutation can happen at any point throughout an organism's development.
2. While the majority of mutations are detrimental to the organism, a tiny percentage (0.1%) may be helpful for crop improvement.
3. Although dominant mutations sometimes occur, recessive mutations are the norm.
4. Both germinal and somatic cells are susceptible to mutation.
5. Both big and tiny mutations are possible.
6. Any gene is susceptible to mutation.
7. Natural factors or artificial induction can cause mutations.
8. Mutations can happen again and again because they are recurrent.
9. Both forward and backward mutations can take place.
10. The majority of mutant alleles exhibit pleiotropy.

Limitations

1. Low-frequency
2. A lot of populations must be screened.
3. Only one or two characters can be improved.
4. The majority of mutations are harmful.
5. Micro mutation identification is quite challenging.
6. Following mutation treatment, there is a limited induction of economically significant mutants.

Mutagens

The term "mutagens" refers to substances that alter DNA. Physical and chemical mutagens are the two categories into which they are divided according to their nature. They produce new traits and increase the genetic diversity of plants by causing genes to mutate at rates higher than the spontaneous background (Lagoda, 2007). The two

most often utilized physical and chemical mutagens in crop improvement programs are gamma radiation (Muralitharan and Rajendran, 2011; Ashadevi *et al.*, 2017) and ethylene methane sulfonate (EMS) (Jabeen and Mirza, 2002; Sheeba *et al.*, 2005; Jayakumar and Selvaraj, 2003; Karthika and Lakshmi, 2006; Kojjagar *et al.*, 2011).

Physical mutagens

Several kinds of radiation are among these mutagens. The mutagenic agent known to affect genes is radiation, which was originally identified in 1920. However, Roentgen discovered X-rays in 1895, while radiation itself was identified in 1890. Marie and Pierre Curie discovered the radioactive element in 1898, whereas Becquerel created radioactivity in 1896. Both ionizing and non-ionizing radiations are part of the physical mutagen. The DNA's double helix structure is broken by ionizing radiation. X-rays, gamma rays, and neutrons are among the frequently employed radiation types. Ionizing gamma rays are the most often utilized physical mutagens (Ashadevi *et al.*, 2017). According to Jadhav *et al.*, (2012), these are electromagnetic radiations that behave physically and affect living things similarly to X-rays. Ionizing radiation is preferred because of its high penetration, high mutagenesis frequency, convenience of usage, and lack of disposal issues (Gupta, 2019). The cellular repair mechanism joins the damaged DNA fragments after they have occurred. These DNA repair systems are only able to withstand low radiation levels, and when exposure to ionizing radiation increases, the organism's genome undergoes irreversible alterations that build up over time. By deleting nucleotides, it alters the DNA sequence, resulting in defective transcripts, reading frame shifts, or inactive protein products (Anonymous, 2019).

Chemical mutagens

A variety of chemical mutations that can



permanently alter the bases of DNA have been found as a result of efforts to prevent aberrations brought on by ionizing radiation and negative impacts. Ethyl Methane is one of the chemical mutagens in addition to MMS, sodium azide, and mustard gas, sulphonate ($\text{CH}_3\text{SO}_2\text{OC}_2\text{H}_5$) is utilized to induce variability (Jayakumar and Selvaraj, 2003; Ashadevi *et al.*, 2017). Chemically generated mutations are commonly used due to their ease of usage, in contrast to irradiation treatment. They also don't need any special tools, and as the frequency of mutations rises, point mutations, single base pair alterations, and single nucleotide polymorphisms are produced. Seeds and in vitro grown tissues of different plants, such as corms, rhizomes, bulbs, tubers, vegetative propagules, etc., are subjected to chemical mutagenic treatments (Suprasna *et al.*, 2012b; Xu *et al.*, 2012). The DNA replication machinery recognizes and modifies guanine and cytosine as adenine or cytosine, respectively, when ethyl methane sulphonate adds an ethyl group to them. A nonsense codon that prevents transcription may arise from this base shifting, which also alters the mRNA and amino acid sequence during protein synthesis, giving mutant plants a different protein (Anonymous, 2019).

Mutagen parameters

Mutations can be harmful in nature. In addition to mutation frequency, mutagenic efficiency, and the efficacy of a specific mutagen dose, it is crucial to understand specific mutagen characteristics during a

mutation experiment, such as the lethal dose-50 (LD 50) dose of a given mutagen. The amount of radiation or chemical mutagen needed to kill 50% of the treated plants is known as the LD 50.

It is useful for figuring out the effective dosage that produces more mutations while lowering mortality. The percentage of altered plants in the overall population following exposure to a mutagenic agent is known as the mutation frequency. To regain a high frequency of beneficial mutations, it is crucial to investigate the mutagenic efficiency and effectiveness of a certain mutagen (Kumar and Mani, 1997). Certain high dosages of mutagenic therapies exhibit greater mutation frequency, mortality, damage, and sterility, while certain lower doses exhibit significantly higher mutation frequency and less of these effects. Since changes are desirable in mutation breeding programs when they are free from undesired genetic alteration only, mutagenic therapies that induce a high mutation rate with less damage and adverse effects are generally greatly sought for.

Mutagenic efficiency is the amount of genetic damage brought about by a mutagen dose in relation to the total biological damage in the first mutated (M1) generation, whereas mutagenic effectiveness is the number of mutations induced per unit dose of a mutagen in unit time (Konzak *et al.*, 1964; Khan and Wani, 2006). These are the formulas provided by Konzak *et al.*, (1965) for determining the mutagenic effectiveness and efficiency.

$$\text{Mutagenic effectiveness} = \frac{\text{Mutation frequency (MF)}}{\text{Time X Concentration or dose}}$$

$$\text{Mutagen efficiency} = \frac{\text{Mutation frequency (MF)}}{\text{Biological damage (Lethality/Injury/Sterility)}}$$



The removal of unwanted genetic modifications to produce desired changes in the mutant is known as mutagenic efficiency. It is determined by dividing the frequency of mutations by the damages—such as mortality, injury, and sterility—that result from mutagenic treatments (Konzak *et al.*, 1965; Gaul *et al.*, 1972). As a result, mutagenic efficiency provides insight into the ratio of mutation to the harmful effects of the mutagen. Therefore, when it comes to reducing a mutagen's effectiveness, mutagenic efficiency is more appropriate than mutagenic effectiveness. According to Jain and Khandelwal (2009), a mutagen with greater efficiency causes comparatively less biological harm in comparison to mutation-induced damage.

Mutation breeding methods

Comparing mutation breeding to traditional hybridization breeding reveals certain benefits. It skips the time-consuming processes of pollination and emasculation because it has only one parent. The source

material is not required in order to enhance a specific attribute. While hybridization works with the variance that already exists in the population, mutations produce new variants that were not previously present in the current populations. However, mutation breeding is very time-consuming and necessitates a thorough and careful screening of numerous mutant populations in order to identify acceptable mutants for subsequent selection. Finding positive mutants of interest becomes essential since mutations alter the DNA at random. Following the crossing of the two homozygous lines, the selection process begins in the third year of hybridization breeding, or the F_2 generation. Dominant mutations in mutation breeding can be found in the M_1 generation, which is the first year or season. However, after M_1 selfing, the heterozygous dominant will segregate in the M_2 generation. Homozygous dominant mutants will be identified by progeny testing and homozygous recessive mutants will be seen in M_2 generation.

Table-1: Differences between hybridization breeding and mutation breeding

Hybridization Breeding	Mutation Breeding
Creation of variation by crossing two genetically dissimilar parents	Creation of variation by treating with mutagens
Trait specific	Trait non-specific
Variation occurs in F_2 generation	Variation occurs in M_1 generation
Works on the variation within the limit of existing variation	New variations can occur
Specific Direction	Directionless
Less laborious	Laborious
Probability of success is more	Probability of success is less, majority are deleterious

Mutation breeding in seed propagating crops

Since chimeras are a major issue with vegetatively propagated crops, mutation breeding in seed-propagated vegetable crops that belong to the groups Solanaceae,

Fabaceae, Cucurbitaceae, and Malvaceae is relatively simple. Obtaining 500–1000 seeds for mutagenic treatment and transporting the seed material to the gamma chamber are simple processes. Producing both mutant and non-mutant seeds is the main obstacle in crop seed propagation. These can



be fixed by using an effective screening technique and keeping a sizable population to find the desired mutations. Thus, the most often used technique in mutant breeding programs is the use of seeds for the mutagenic treatments.

Mutation breeding in self-pollinated crops

In self-fertilized crops, the mutant traits are quite simple because they occur frequently in nature. It is recommended that these materials be autogamous and undergo phenotypic screening after at least M2 generation. The plants in this generation will undergo isolation in order to identify the recurrent mutant characteristic.

Mutation breeding in cross pollinated crops

Crops that are mostly cross-fertile are

Table-2: Differences between seed propagated and vegetatively propagated crops for mutation breeding

Seed propagated species	Vegetatively propagated species
Plant material used is seed or pollen unicellular starting material	Plant material is apical or auxiliary buds
Next generation proceeds sexually	Next generation proceeds vegetatively
Further variation occurs due to selfing	Mutation is the only source of variation
The mutagenic generations are indicated as M1, M2, M3	The mutagenic generations are indicated as M1V1, M1V2, M1V3....
No problem of Chimeras	Chimeras are the major problem
Selection starts from M1 or M2 generation	Actual selection starts from M1V4
Comparatively consumes less time	Comparatively consumes more time

Past accomplishments

In 2009, the FAO/IAEA mutant variety

heterozygous and show a high degree of inbreeding depression, which makes the labor tiresome. It results in a significant variance in M2 production during open pollination and selfing. There are a few major mutants of interest that can be found. The employment of mutant breeding techniques is more complicated for plant species that include self-infertility mechanisms, such as self-incompatibility.

Mutations in vegetatively propagated species

Mutation breeding in asexually propagated species like cassava, sweet potato, potato, and taro differs from seed propagated crops in several ways. Mutagenic therapy in multi-cellular, actively dividing tissues, such as apical or auxiliary buds, requires careful inspection for chimeric mutants.

database includes around 3168 mutant cultivars from over 200 plant species, with a total of 3218 as of 2014.

Table-3: Significant achievements of Vegetable crops in India through Mutation Breeding

Crop	Variety	Mutant type
Tomato	S-12	X-ray mutant of Sioux
	Maruthan	Mutant of CO-1
	PKM -1	Mutant of Annagi



Crop	Variety	Mutant type
Chilli	Pusa Lal Meeruti	Gamma ray mutant of Meeruti
French Bean	MDU-1	Gamma Ray mutant of K-1
Hyacinth bean	PusaParvati	X-Ray mutant of Wax pod
	CO-10	Gamma ray mutant of CO-6
	CO-9	Spontaneous mutant
Okra	EMS-8	EMS treated mutant of Pusa Sawani
	MDU-1	Gamma ray mutant of Pusa Sawani
Bitter gourd	MDU-1	Gamma ray mutant of MC-103
Palak	Jobner Green	Spontaneous mutant from local cultivar
Pea	L-166 (Hans)	-

The list of mutant varieties released in abroad in various vegetable crops is given in Table-4 (Kalloo and Kalloo, 1988).

Table-4: Significant achievements of Vegetable crops in world through Mutation Breeding

Crop	Variety	Characteristic
Tomato	Luch 1	Early ripening mutant
	M47/13	High yield
French bean	Sanilac, Seeway, Seafarer,	Early maturity and disease
	Gratiot, Alpha	resistance
Pea	Wasata and acasia	Leafless mutants
	Starl	Suitable for mechanical
		harvesting
Onion	Compass	High yield
Cassava	Ten bankye	African Cassava Mosaic
		Virus resistance
Pea	HUVP 1 and HUVP 2	Powdery mildew resistance 2

Conclusion

Global food demand necessitates higher crop yields, driving the need for improved varieties. Mutation breeding creates new variations for desirable traits like yield and disease resistance, especially when existing variation is limited. While beneficial, it also carries risks like harmful mutations and lengthy screening processes. Modern techniques like molecular markers and TILLING enhance mutation breeding, making it a valuable tool alongside other breeding method.

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Rural Women and the Use of Renewable Energy: A Pathway to Sustainable Livelihoods

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Introduction

Rural women play a central role in agriculture, household management, and natural resource conservation. From sowing and harvesting crops to collecting fuel, fetching water, and caring for livestock, their daily lives are closely linked with energy use. However, in many rural areas, women still depend heavily on traditional sources of energy such as firewood, crop residues, and dung cakes. These sources are not only time-consuming to collect but also pose serious health and environmental risks.

In recent years, renewable energy has emerged as a powerful tool for transforming rural livelihoods. Clean and sustainable energy sources such as solar, biogas, wind, and improved biomass technologies offer immense benefits to rural women by reducing drudgery, improving health, saving time, and enhancing income opportunities. The integration of renewable energy in rural households and farms is therefore not just an environmental necessity but also a step toward women's empowerment.

Energy Use and Challenges Faced by Rural Women

In most rural households, women are the primary managers of domestic energy. They spend several hours each day collecting fuelwood and cooking on traditional chulhas. Prolonged exposure to smoke from inefficient cooking practices leads to respiratory diseases, eye problems, and fatigue. According to various studies, indoor air pollution is one of the major health hazards for rural women.

Apart from health issues, the time spent on fuel collection reduces opportunities for education, skill development, and income-generating activities. Environmental degradation caused by excessive use of

firewood further increases the burden on women, as fuel sources become scarce and distant.

Renewable Energy Technologies Benefiting Rural Women

Renewable energy technologies suitable for rural areas are diverse and can be adapted to local needs, resources, and occupations of women. Some important and emerging technologies include:

1. Solar Energy Technologies

Solar energy is one of the most accessible renewable sources for rural households. Solar lanterns and solar home lighting systems provide safe and reliable lighting, allowing women to extend productive hours for household and income-generating



work. Solar cookers reduce dependence on firewood and LPG, while solar dryers are increasingly used by rural women for drying fruits, vegetables, spices, and medicinal plants, improving product quality and market value. Solar-powered irrigation pumps help women farmers save labor and reduce expenditure on diesel.

2. Biogas and Bioenergy Technologies

Biogas plants are highly suitable for rural households with livestock. They provide clean fuel for cooking and lighting while effectively managing animal waste. Advanced biogas digesters and community biogas plants serve multiple households and reduce individual costs. Bioenergy technologies also include biomass briquetting and pellet-making units, which convert agricultural residues into efficient fuel, creating income opportunities for women-led enterprises.

3. Improved Cookstoves and Clean Cooking Solutions

Improved biomass cookstoves and smokeless chulhas significantly reduce smoke emissions and fuel consumption. New-generation cookstoves are designed to be fuel-efficient, affordable, and user-friendly. Some models are integrated with chimneys or forced-draft systems, further improving indoor air quality and health outcomes for women.

4. Solar-Based Livelihood Technologies

Renewable energy is increasingly being linked with rural livelihoods. Solar-powered sewing machines, flour mills, oil expellers, milk chillers, and food processing units enable women to undertake small-scale enterprises at the village level. These technologies reduce operating costs, increase productivity, and provide year-round income opportunities.

5. Water and Sanitation Technologies

Solar-powered water purification systems and pumps ensure access to safe drinking

water, reducing the burden on women who traditionally fetch water from distant sources. Renewable energy-based sanitation solutions, such as biogas-linked toilets, improve hygiene while generating energy.

6. Wind, Micro-Hydel, and Hybrid Systems

In regions with suitable geographic conditions, small wind turbines and micro-hydel systems provide reliable power to rural households and community centers. Hybrid systems combining solar, wind, and battery storage ensure uninterrupted energy supply, especially in remote villages.

7. Information and Communication Technologies (ICT) Powered by Renewables

Solar-powered mobile charging stations, digital kiosks, and community information centers enable women to access agricultural advisories, market information, digital payments, and online training. These technologies bridge the digital divide and strengthen women's participation in the rural economy.

8. Energy Storage and Smart Technologies

Advances in battery storage, solar inverters, and smart energy management systems make renewable energy more reliable and efficient. Women trained in basic operation and maintenance of these systems become local energy managers, enhancing sustainability and technical self-reliance.

Benefits of Renewable Energy for Rural Women

Reduction in Drudgery and Time Saving

Renewable energy reduces the physical burden of fuel collection and cooking. The saved time can be utilized for education, self-help group activities, or income generation.

Improved Health and Well-Being

Clean cooking technologies significantly reduce indoor air pollution, leading to better respiratory health and overall well-being of women and children.



Economic Empowerment

Access to reliable energy enables women to engage in small enterprises such as food processing, tailoring, dairy activities, and handicrafts. Solar-powered machines and tools increase productivity and income.

Environmental Conservation

Renewable energy helps conserve forests, reduce greenhouse gas emissions, and promote sustainable use of natural resources, ensuring a better environment for future generations.

Social Empowerment

When women are involved in the installation, maintenance, and management of renewable energy systems, their confidence, decision-making power, and social status improve.

Role of Self-Help Groups and Institutions

Women's self-help groups (SHGs), cooperatives, and community organizations play a crucial role in promoting renewable energy adoption. Through awareness programs, training, and micro-financing, these groups help women understand the

benefits of clean energy and access government schemes.

Government initiatives such as solar mission programs, biogas subsidy schemes, and rural electrification projects have created new opportunities for women. Training rural women as energy entrepreneurs and technicians not only ensures sustainability of projects but also generates local employment.

Conclusion

Renewable energy has the potential to transform the lives of rural women by improving health, reducing drudgery, enhancing income, and protecting the environment. When women gain access to clean and sustainable energy, the benefits extend beyond households to agriculture, rural economy, and society as a whole. Empowering rural women through renewable energy is not merely a technological intervention; it is a holistic approach to sustainable development. By placing women at the center of energy solutions, we can build resilient rural communities and move toward a greener and more equitable future.





Medicinal Properties of Bael (*Aegle marmelos*): A Comprehensive Review

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Introduction

Bael (*Aegle marmelos*) is a well-known medicinal plant that has been widely used in traditional systems of medicine such as Ayurveda, Siddha, and Unani for centuries. Almost all parts of the plant, including the fruit, leaves, bark, roots, and seeds, possess therapeutic value. This review summarizes the medicinal properties, phytochemical composition, and therapeutic applications of bael based on traditional knowledge and scientific studies. Bael contains several bioactive compounds such as alkaloids, flavonoids, tannins, coumarins, terpenoids, and phenolic compounds, which are responsible for its pharmacological activities. The plant exhibits a wide range of biological effects, including gastroprotective, antimicrobial, antidiabetic, anti-inflammatory, antioxidant, hepatoprotective, cardioprotective, and immunomodulatory properties. Bael is especially effective in the management of gastrointestinal disorders, diabetes, infections, and oxidative stress-related conditions. Scientific evidence supports many of its traditional uses, highlighting its potential role in modern herbal medicine. Overall, bael is a valuable natural resource with significant medicinal importance, and further clinical studies are needed to standardize its use and promote its integration into contemporary healthcare systems.

Medicinal plants have played a crucial role in human health since ancient times and continue to serve as an important source of therapeutic agents worldwide. A significant proportion of the global population still relies on traditional plant-based medicines for primary healthcare due to their effectiveness, accessibility, and relatively low cost. The increasing interest in natural remedies has further emphasized the importance of scientifically evaluating medicinal plants that have long been used in traditional systems of medicine. Among the numerous medicinal plants, bael (*Aegle marmelos*) occupies a prominent position

because of its wide range of pharmacological properties. Bael is a sacred and medicinal tree native to the Indian subcontinent and has been extensively used in traditional medical systems such as Ayurveda, Siddha, Unani, and various folk practices for several thousand years. The plant holds cultural and religious significance, particularly in India, which has contributed to its preservation and continued therapeutic use. Almost all parts of the plant, including the fruit, leaves, bark, roots, and seeds, are known to possess medicinal value and are utilized in different herbal preparations. In recent decades,



scientific investigations have increasingly supported the traditional claims associated with bael. Various experimental and clinical studies have reported that bael exhibits antimicrobial, anti-inflammatory, antidiabetic, antioxidant, hepatoprotective, and gastroprotective activities. These pharmacological effects are primarily attributed to the presence of diverse bioactive compounds such as alkaloids, flavonoids, tannins, coumarins, terpenoids, and phenolic compounds. With the growing demand for safe, effective, and plant-derived therapeutic agents, bael has gained considerable attention in modern pharmacological research. A comprehensive understanding of its phytochemical constituents and medicinal properties is essential for its rational use, standardization, and potential incorporation into modern healthcare systems. Therefore, the present article aims to provide a detailed and systematic review of the medicinal properties of bael (*Aegle marmelos*), its phytochemical composition, therapeutic applications, and its significance in contemporary medicine.

Botanical Description and Distribution

Bael (*Aegle marmelos*) belongs to the family Rutaceae. It is a medium-sized deciduous tree that can grow up to 10–15 meters in height. The leaves are trifoliate, aromatic, and glossy, while the flowers are greenish-white and fragrant. The fruit is spherical or oval with a hard woody shell and contains aromatic pulp with numerous seeds. Bael is widely distributed throughout India, Sri Lanka, Nepal, Bangladesh, Myanmar, Thailand, and other Southeast Asian countries. It thrives in dry forests and can tolerate poor soil conditions, making it a hardy and drought-resistant plant.

Phytochemical Composition of Bael

The medicinal properties of bael are attributed to its rich phytochemical profile. Different parts of the plant contain a variety

of bioactive compounds, including:

- Alkaloids (e.g., aegeline)
- Flavonoids
- Tannins
- Coumarins
- Terpenoids
- Phenolic compounds
- Essential oils
- Glycosides
- Saponins

The fruit pulp is rich in carbohydrates, vitamins (especially vitamin C and B-complex), minerals, and dietary fiber. Leaves contain essential oils and alkaloids, while the bark and roots are rich in tannins and phenolic compounds. These constituents collectively contribute to the plant's therapeutic efficacy.

Medicinal Properties of Bael

4.1 Gastrointestinal Benefits

One of the most well-known medicinal uses of bael is its effectiveness in treating gastrointestinal disorders. Bael fruit has been traditionally used to manage diarrhea, dysentery, constipation, and indigestion.

- Unripe bael fruit is highly effective against chronic diarrhea and dysentery due to its astringent and antimicrobial properties.
- Ripe bael fruit acts as a mild laxative and helps relieve constipation.
- Bael improves digestion by stimulating digestive enzymes and reducing intestinal inflammation.

Its ability to restore normal bowel function makes bael a valuable natural remedy for digestive health.

4.2 Antimicrobial and Antiviral Activity

Bael exhibits strong antimicrobial properties against a wide range of bacteria, fungi, and viruses. Extracts from bael leaves, fruit, and bark have shown inhibitory effects against pathogens such as *Escherichia coli*, *Salmonella*, *Staphylococcus aureus*, and *Candida* species.

The antimicrobial action of bael is mainly



due to the presence of coumarins, alkaloids, and essential oils, which disrupt microbial cell membranes and inhibit growth. This property supports the traditional use of bael in treating infections, wounds, and gastrointestinal diseases caused by pathogens.

4.3 Antidiabetic Properties

Bael has demonstrated significant antidiabetic activity in both traditional practice and experimental studies. Leaf extracts of bael are commonly used to regulate blood glucose levels in diabetic patients.

Bael helps in:

- Enhancing insulin secretion
- Improving glucose uptake by tissues
- Reducing oxidative stress associated with diabetes

Regular consumption of bael leaf extract has been found to lower fasting blood glucose levels and improve lipid profiles, making it beneficial in the management of type 2 diabetes mellitus.

4.4 Anti-inflammatory and Analgesic Effects

Inflammation is a common underlying factor in many chronic diseases. Bael possesses notable anti-inflammatory and analgesic properties, which make it effective in reducing pain and swelling.

Bioactive compounds such as flavonoids and phenolic acids inhibit inflammatory mediators like prostaglandins and cytokines. As a result, bael is traditionally used to relieve:

- Joint pain
- Arthritis
- Fever
- Headaches

Its natural anti-inflammatory action offers a safer alternative to synthetic anti-inflammatory drugs.

4.5 Antioxidant Activity

Oxidative stress caused by free radicals contributes to aging and various diseases,

including cancer and cardiovascular disorders. Bael is a rich source of natural antioxidants, which neutralize free radicals and protect cells from damage.

The antioxidant activity of bael is attributed to flavonoids, tannins, and phenolic compounds. These antioxidants help:

- Prevent cellular damage
- Slow the aging process
- Enhance immune function
- Reduce the risk of chronic diseases

4.6 Hepatoprotective Effects

Bael has been traditionally used to support liver health. Scientific studies suggest that bael extracts protect the liver from toxic substances and oxidative damage.

Bael helps in:

- Reducing liver inflammation
- Enhancing detoxification enzymes
- Preventing liver cell degeneration

This hepatoprotective property makes bael useful in managing liver disorders caused by alcohol, drugs, or environmental toxins.

4.7 Cardioprotective Properties

Bael contributes to cardiovascular health by regulating blood lipid levels and improving heart function. Its antioxidant and anti-inflammatory properties help reduce the risk of atherosclerosis and hypertension.

Regular consumption of bael may:

- Lower cholesterol levels
- Improve blood circulation
- Reduce oxidative stress on heart tissues

Thus, bael plays a supportive role in maintaining heart health.

4.8 Immunomodulatory Activity

Bael strengthens the immune system by enhancing the body's natural defense mechanisms. It stimulates the production of immune cells and improves resistance to infections.

The immunomodulatory effects of bael are especially beneficial in:

- Recurrent infections



- Seasonal illnesses
- General weakness and fatigue

Traditional and Therapeutic Uses

In traditional medicine systems:

- Leaves are used for diabetes, fever, and inflammation.
- Fruit pulp is used for digestive disorders.
- Bark and roots are used for fever, malaria, and wound healing.
- Seeds possess antimicrobial and anti-inflammatory properties.

Bael is also used in the preparation of herbal formulations, tonics, and functional foods.

Safety and Toxicity

Bael is generally considered safe when consumed in recommended amounts. However, excessive intake, especially of unripe fruit or concentrated extracts, may cause gastrointestinal discomfort. Pregnant

and lactating women should consult healthcare professionals before using bael medicinally.

Conclusion

Bael (*Aegle marmelos*) is a highly valuable medicinal plant with a broad spectrum of therapeutic properties. Its effectiveness in treating digestive disorders, diabetes, inflammation, infections, and oxidative stress highlight its importance in both traditional and modern medicine. The rich phytochemical composition of bael contributes to its diverse pharmacological activities. With growing interest in natural and plant-based therapies, bael has the potential to play a significant role in the development of safe and effective herbal medicines. Further clinical research and standardization are essential to fully harness its medicinal potential and integrate it into contemporary healthcare systems.





Scientific Approaches to Post-Harvest Care in Floriculture

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Introduction

Floriculture has become a promising diversification option within agri-business, growing rapidly at over 15% annually for the past two decades. This growth is fuelled by urbanization, rising incomes, and evolving consumer preferences, increasing demand for both loose and cut flowers in India. The expanding middle class has further boosted domestic consumption. While India's floriculture exports have grown since the 1990s, the sector still has untapped global potential. It includes both open-field cultivation of loose flowers and protected cultivation of high-value cut flowers. However, one of the sector's major challenges is the high perishability of flowers, leading to post-harvest losses of 30–40% of farm value. These losses are especially critical for long-distance and export markets where maintaining quality is essential. Flowers undergo complex physiological changes after harvest involving various plant parts, which differ by species and cultivar. Quality and vase life are influenced by the plant's condition at harvest, environmental conditions during handling and storage, and the use of appropriate post-harvest treatments. To reduce losses and preserve flower quality, skilled and gentle handling is crucial throughout the supply chain. Addressing these challenges is vital for India to fully capitalize on its floriculture potential in both domestic and international markets.

1. Pre harvest factors
2. Harvest factors
3. Post-harvest factors

Pre-harvest factors

Genetic or inherent makeup: Post-harvest lasting quality of flower species and cultivars vary considerably due to differences in their genetic make-up. Gladiolus varieties White Prosperity, Sancerre, Suchitra, Eurovision, Nova Lux, Rose Supreme and Trader Horn possess the better vase-life.

Harvest Factors: Flowers should be harvested during the coolest times of the

day-early morning or late evening to reduce respiration and preserve freshness. Avoid harvesting when blooms or foliage are wet, as moisture encourages microbial growth and reduces vase life. Remove foliage from stem sections that will be submerged in water to prevent bacterial contamination. For hardwood stems, a slanted cut improves water uptake. Some flowers release latex when cut, which can block water absorption; in such cases, dipping the stem ends briefly in hot water (80–90°C) helps coagulate the latex and restore vascular flow, ensuring better hydration and longevity.



Optimum stage of harvesting in commercial flowercrops

Name of crop	Stage of development for harvesting
Tuberose	More than 2 pairs of floret open
Rose	Red & pink cultivars 1st 2 petals beginnings to unfold, calyx reflexes below a horizontal position. Yellow cultivar slightly earlier than red & pink White cultivar slightly later than red & pink
Chrysanthemum	Standard cultivar outer petals fully enclosed Spray cultivar single open but before anthesis Anemones open but before disk flowers start to elongate Pompon & centre of boldest flower decorative fully open
Carnation	Paint brush stage

Causes of Deterioration of Harvested Flowers

Mechanical Injury: Breaking of florets or spikes during harvesting, handling, storage and packaging accelerate senescence of petals.

Plugging of Xylem Vessels of cut Flowers: Presence of micro-organisms like bacteria, yeasts or fungi in the holding solution, which leads to rapid deterioration of vase-life of cut flowers. Moisture Content: Excessive loss of moisture of the harvested flowers reduces their life.

Water Quality: The water of fresh cut flowers should have a pH of 3.5–4.5, since acidic solutions move more readily up the stems than neutral or alkaline solutions. The optimum amount of total dissolved solids in water for cut flowers should be less than 200 ppm, otherwise these can block the strands through which water travels up to the stem.

Ethylene Gas: It is a hormone which speeds up senescence process of flowers. It causes flower and petal drop, retards flower development, shrivels up flowers, and result in premature yellowing and loss of foliage.

Heat Damage: Apart from external heat, flowers themselves also generate heat. Once they have reached a certain temperature, heat build-up increases. High temperature

encourages production of ethylene gas as well as postharvest diseases.

Post-harvest factors

Precooling: Pre-cooling is a critical post-harvest practice in floriculture that involves rapidly removing the field heat from freshly harvested flowers to slow down their metabolic activity and delay senescence. Since flowers are highly perishable and sensitive to temperature fluctuations, pre-cooling helps maintain freshness, reduce respiration and transpiration rates, and extend vase life.

Conditioning/hardening

Conditioning is a post-harvest technique that restores turgor in wilted flowers by placing them in demineralized, germicide-treated, and acidified water, sometimes with wetting agents like Tween 20 to boost water uptake. Impregnation involves short treatments with silver nitrate, nickel, or cobalt chloride to reduce microbial growth and ethylene production, benefiting flowers like Gerbera, Carnation, Chrysanthemum, and Gladiolus.

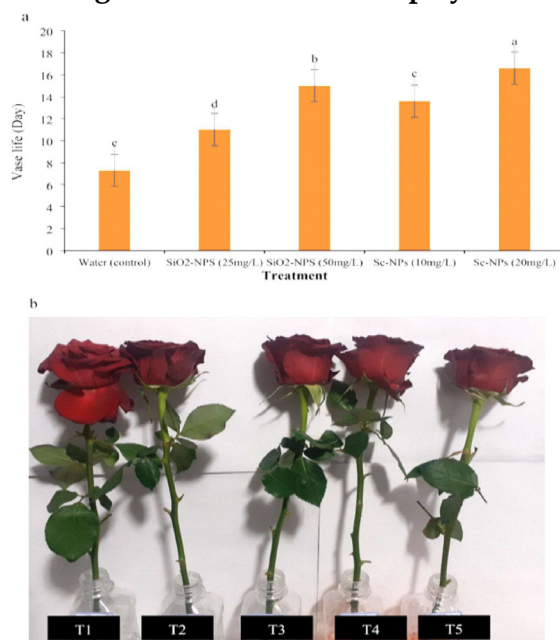
Pulsing

Treating the flowers with high concentration of sucrose and germicide for a short period of time, in order to improve the shelf life and to promote flower opening. Pulsing is beneficial especially for flowers destined



for long storage period or long distance transportation.

Effect of different concentrations of SiO₂-NPs and Se-NPs on (a) *R. hybrida* 'Black Magic' vase life and (b) display life.



Seyed Hajizadeh *et al.*, 2024

Bud opening

Use of germicides, sucrose and hormonal solution to promote the opening of immature buds in crops like chrysanthemums, rose, carnation, gladiolus, and snapdragon.

Grading, bunching and packaging

After harvesting the flowers should be graded according to various grades as perspecification for local and distant market. Then these should be pulsed and made into bunches of 5, 10, 20, 50, 100. Cut flower should be packed in corrugated cardboard boxed or sleeves. Packaging must ensure protection of flowers against physical damage and for this cotton or newspaper can be used as cushion.

Cold storage

After pre-cooling and pulsing the flowers can be stored at low temperature i.e. in cold

store to regulate the flower market or to avoid the glut in the market. Controlled atmospheric (CA) modified atmospheric (MA) or hypobaric (LP) storage method can be used to enhance the post-harvest life of flower.

Packing and transporting

Packaging plays a crucial role in delivering garden-fresh flowers to consumers by minimizing transpiration, respiration, and cell division during transport to extend shelf life. Before packing, flowers should be properly dried and treated with systemic insecticides and miticides. Packaging must protect against physical damage, moisture loss, and harmful external conditions. Corrugated fiberboard boxes are ideal. Flowers prone to geotropic bending should be transported upright. Maintaining optimal low temperatures and high relative humidity (95–98%) during precooling and shipment is essential to preserve freshness and quality during transportation.



Holding solutions

After pulsing and storage, flowers are held in a solution containing sucrose, germicide ethylene inhibitor and growth regulator. It's basically aimed at providing nourishment to the cut flowers. The flowers can be kept in holding solution either at wholesaler, retailer or consumer level.

Use of Preservatives/Post-harvest chemical treatments

Post-harvest chemical treatments play a vital role in maintaining the quality,



freshness and vase life of cut flowers. Due to their highly perishable nature, cut flowers require immediate and effective treatments to minimize senescence, microbial growth and water stress. Preservatives are specially formulated solutions used after harvest to prolong vase life by providing essential nutrients and reducing physiological deterioration.

Types of Post-Harvest Treatments and Their Functions

1. Floral Preservatives

These are commercial or custom-made solutions containing

- **Sugars (2–4%):** Provide respiratory substrates.
- **Biocides (e.g., 8-HQC, sodium hypochlorite):** Inhibit microbial growth in vase water.
- **Acidifiers (e.g., citric acid):** Lower pH to enhance water uptake.

2. Pulsing

A short-term treatment (4–24 hours) using high concentrations of sugars or chemicals to:

- Restore turgidity
- Delay senescence
- Improve transport resilience

Common pulsing solutions: Sucrose (up to 20%), STS (Silver Thiosulfate) for ethylene-sensitive flowers.

3. Impregnation Treatment

Flowers are dipped in a solution of silver

nitrate, nickel chloride, or cobalt chloride for a few minutes.

- Controls microbial growth
- Inhibits ethylene production
- Effective for Gerbera, Carnation, Gladiolus and Chrysanthemum

4. Anti-ethylene Treatments

- **STS (Silver Thiosulfate):** Blocks ethylene receptors; widely used in ethylene-sensitive crops like carnations.
- **1-MCP (1-Methylcyclopropene):** A non-toxic ethylene action inhibitor used as a gaseous treatment.

Conclusion

Effective post-harvest management is vital to maintaining the quality, appearance, and vase life of highly perishable cut flowers. Key steps—such as pre-cooling, conditioning, pulsing, preservatives use, proper packaging, and cold chain maintenance—help reduce physiological deterioration and microbial damage. Scientifically proven methods, including biocides, acidifiers, anti-ethylene agents, and floral preservatives, greatly enhance flower longevity. As domestic demand and export opportunities grow, improved post-harvest practices minimize losses and boost growers' profitability. Ongoing research, innovation, and training are essential to ensure consistent quality and strengthen India's position in the competitive global floriculture industry.





'Climate Migration': Displacement From Farm to City in the Warming Anthropocene

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Introduction

In recent years, climate change has shifted from being an environmental concern to a lived human reality. Climate change is no longer an abstract environmental debate; it has become a vivid reason behind agrarian crisis. Rising temperatures, erratic rainfall, prolonged droughts, severe floods, cyclones and sea-level rise are no longer distant projections - they are reshaping livelihoods across the globe. One of the most significant yet under-discussed consequences of this transformation is climate migration: the movement of people driven, directly or indirectly, by climate-related stresses.

What Is Climate Migration?

Climate migration refers to the displacement or relocation of individuals or communities due to environmental changes linked to climatic variability and climate change. Unlike traditional migration - which is driven by economic opportunity or political instability, climate migration is often forced by deteriorating living conditions caused by climate-caused serious threats like crop failures, water scarcity, inhabitat loss or recurring natural disasters. It is s'neo-emerging challenge' because, while migration itself is not new, climate-induced migration is arising in an intensified form, along with general complexification. As environmental stress increases - more people are compelled to move, not by choice, but by necessity.

Why Is Climate Migration Increasing?

Several interlinked factors are contrib-

uting to the rise of climate migration:

First, extreme weather events are becoming more frequent and intense. Floods, cyclones and heatwaves destroy homes, infrastructure and affecting the livelihood pattern. When rebuilding becomes impossible or too costly, families have to relocate permanently.

Second, slow-onset environmental changes such as desertification, coastal erosion and salinization gradually undermine agricultural productivity. In rural regions, where inhabitants are dependent on farming, declining yields translate directly into income insecurity, pushing households toward urban areas.

Third, water scarcity is emerging is also as a powerful migration driver. When groundwater levels fall and rainfall becomes unpredictable, rural livelihoods collapse. Migration emerges as a coping strategy.



Climate Migration and the Rural Agrarian Economy

In agrarian economies, livelihoods are deeply tied to natural resources. So when climate variability reduces crop yields, increases input uncertainty or destroys assets, farm households naturally experience income instability. Agricultural economics explains this as a rise in production risk and a decline in expected farm profitability. When risks exceed coping capacity, migration becomes the rational household option for survival as well as income diversification. From an economic perspective, climate migration is not merely displacement; it is an adaptive response to declining marginal returns in agriculture. Households compare expected farm income under uncertain climatic conditions with potential earnings in urban or non-farm sectors. When agricultural risk-adjusted returns fall, migration becomes economically justified.

However, this shift alters rural labour supply, cropping decisions and long-term investment patterns. Seasonal migration may reduce available labour during peak agricultural operations, affecting the productivity. Permanent migration may lead to land abandonment or shifts toward low-input crops.

Role of Agricultural Extension in Climate-Stressed Regions

Agricultural extension may act as a critical frontline defence in reducing distress migration. As we know, extension systems are naturally devised to transfer knowledge, build capacity and promote technology adoption. In the context of climate migration, extension must go beyond yield enhancement or simple coping capacity building, rather with a broader focus on resilience-building. Climate-smart agriculture, water-use efficiency, drought-

tolerant varieties, integrated farming systems and risk-reducing technologies become central tools. Extension services can equip farmers with adaptive strategies that stabilize income under climatic stress – a calculative strategy of reducing the push factors behind migration.

The Indian Context

India is particularly vulnerable to climate migration. A large population of the country is dependent on climate-sensitive sectors, such as agriculture and fisheries, environmental shocks have immediate socioeconomic consequences.

1. Coastal states face threats from sea-level rise and cyclones. The Sundarbans region in coastal West Bengal, for instance, has witnessed displacement due to rising tides and erosion.

2. In drought-prone regions of Maharashtra, Rajasthan and parts of central India, recurring crop failures have accelerated rural-to-urban migration. Seasonal migration is increasingly becoming permanent, as climate variability disrupts traditional livelihoods.

3. Heatwaves in northern and central India are also making certain regions less habitable, particularly for outdoor labourers. As living conditions worsen, migration emerges as a survival strategy rather than an economic aspiration.

The Road Ahead

Climate migration represents one of the defining human challenges of the 21st century. It sits at the intersection of environment, economics, extension, community science, human rights and developmental studies. As climate change accelerates, mobility will increasingly become part of the adaptation landscape. Recognizing climatic migration as a structural reality rather than a temporary disturbance is the first step. Building resilient rural economies, climate-ready



cities and inclusive policy frameworks will determine whether climate migration becomes a humanitarian crisis or a managed transition. Movement may not always be a choice, but with thoughtful planning - it need not become a tragedy.

Conclusion

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Innovative Biointensive Pest Management: Improving Yields in Important Vegetable Crops

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Introduction

India is the second-largest producer of vegetables after China. Vegetables are highly susceptible to insect pests and diseases, and the indiscriminate use of chemical pesticides has caused serious ecological problems, including the destruction of natural enemy populations, harm to non-target organisms, residues in food and water, and the development of pesticide resistance. Bio-intensive pest management (BIPM) has emerged as a modern approach in Indian agriculture, attracting farmers due to its potential to increase income while reducing ecological harm. This shift is driven by growing awareness among consumers and concerns over environmental degradation. However, it should be recognized that chemical pesticides cannot be completely replaced and remain necessary under severe pest infestations. In this context, bio-intensive pest management practices for major vegetable crops, developed through scientific research and integrated into IPM frameworks, are discussed.

Integrated Pest Management (IPM)

Integrated Pest Management (IPM) provides a sustainable, ecosystem-focused approach by integrating various pest control tactics to reduce economic, health, and environmental risks. It emphasizes prevention and monitoring ahead of routine pesticides, blending biological, cultural, physical, and chemical methods as required.

These IPM programs focused on reducing and rationalizing pesticide use by encouraging farmers to adopt cultural and manual-mechanical practices, given the lack of effective bio agents. Their value stems

from knowledge as the fourth key factor of production influencing farmers' decision-making, productivity, and profitability. IPM programs have proven highly successful in cutting pesticide use and delivering additional benefits. However, as investments in these programs rise, questions arise about their economic returns, which accrue over time and are expected to be substantial.

IPM Tactics That Save Farms

Biological control: Involves the use of natural enemies such as predators, parasitoids, and pathogens to suppress pest populations. This approach reduces



dependence on chemical pesticides and helps maintain ecological balance.

Cultural practices: Include farming techniques such as crop rotation, intercropping, timely planting, and proper field sanitation, which limit pest breeding sites and interrupt their life cycles.

Physical control: Consists of using physical methods such as barriers, traps, nets, mulches, and manual removal to prevent pests from reaching crops or to reduce their population.

Chemical control: When other methods are insufficient, selective and environmentally safe pesticides are applied judiciously to minimize damage to non-target organisms and delay the development of pest resistance.

Key Benefits of Integrated Pest Management (IPM)

Integrated Pest Management (IPM) offers numerous benefits by promoting environmentally responsible and economically viable pest control practices. By reducing the dependence on chemical pesticides, IPM minimizes environmental pollution and protects non-target organisms such as beneficial insects, wildlife, and aquatic life.

The use of diverse pest control strategies helps slow the development of pest resistance, ensuring long-term effectiveness and maintaining ecological balance. IPM also improves economic efficiency by emphasizing prevention and combining multiple control methods, thereby lowering overall pest management costs and reducing losses caused by pesticide resistance and pest resurgence.

In addition, IPM supports sustainable agriculture by enhancing soil health, biodiversity, and ecosystem resilience, which are essential for long-term productivity and food security. Reduced pesticide use further safeguards human health by lowering exposure risks for farmers, farm

workers, and consumers. Ultimately, IPM contributes to improved crop quality and yield, ensuring a consistent supply of safe, high-quality agricultural produce.

What Is Bio-intensive Integrated Pest Management (BIPM)?

Bio-intensive IPM is defined as a systems approach to pest management based on an understanding of pest ecology. It begins with steps to accurately diagnose the nature and source of pest problems, and then relies on a range of preventive tactics and biological controls to keep pest populations within acceptable limits. Reduced-risk pesticides are used if other tactics have not been adequately effective, as a last resort, and with care to minimize risks

Bio-intensive IPM is a sustainable approach for pest management that integrates cultural practices, host plant resistance, biological control (predators, parasitoids, and pathogens), biorational tools, biopesticides, and molecular approaches to achieve economic, ecological, and social benefits

How BIPM Differs from Conventional Pest Control

A key difference between conventional IPM and bio-intensive IPM is that bio-intensive IPM focuses on proactive measures to redesign the agricultural ecosystem, making it unfavorable for insect pests while supporting their natural enemies, such as predators and parasitoids. At the same time, it still incorporates many of the same components used in conventional IPM.

Key Components of Modern Bio-intensive IPM

Modern bio-intensive integrated pest management relies on a combination of eco-friendly practices such as crop rotation, summer ploughing, fallowing, intercropping, pruning, mulching, proper spacing, timely planting, and trap cropping, along with the use of pest-resistant crop varieties.



It also includes beneficial organisms like predators, parasitoids, biocontrol agents, and mycorrhizal fungi; plant-based products such as bio-fumigation materials, oil cakes, farmyard manure, crop residues, green manures, and other organic amendments; physical methods like hot-water treatment of planting material and soil solarization; and safe bio-rational tools such as pheromones.

Bio-Intensive Pest Strategies for India

Bio-intensive pest management focuses on maintaining a natural balance between crop pests and beneficial insects in the farm ecosystem. This balance is often disturbed by common farming practices, even though farmers still need to produce good-quality crops and earn profits. Therefore, it is important to use a well-planned combination of different pest control methods to manage insect pests effectively.

In India, however, scientific studies and practical models on bio-intensive pest management are still limited. This approach requires a shift from traditional pest control methods to more ecology-based practices. It encourages creating suitable habitats for beneficial organisms, improving soil health, conserving uncultivated areas to support biodiversity, growing intercrops, and protecting useful insects. The use of natural enemies produced in laboratories or multiplied on-farm, along with plant-based products and other bio-agents, can further strengthen bio-intensive pest management. These methods are particularly useful when natural enemies alone are not effective and when chemical control is not environmentally safe.

Solanaceous Crops: Key Vegetables in India

Solanaceous vegetables are some of the most economically important crops in India. This group includes tomato (*Lycopersicon esculentum* Mill), chillies (*Capsicum annuum*),

and brinjal (*Solanum melongena* L.), which are widely cultivated across the country for their taste, nutritional value, and essential role in the Indian diet.

Common Pests of Tomato

Tomatoes, in particular, are highly vulnerable to a range of pests that can significantly reduce yield and quality. Among the most damaging are the fruit borer (*Helicoverpa armigera* Hubner), the serpentine leaf miner (*Liriomyza trifolii*), whiteflies (*Bemisia tabaci*), and thrips (*Frankliniella occidentalis*).

Whiteflies and thrips are especially concerning because they not only feed on the plants but also act as carriers of viral diseases, which can further threaten crop production.

Integrated BIPM Strategies

Integrated Bio-Intensive Pest Management (BIPM) strategies that combine multiple biological and botanical approaches have proven highly effective in tomato cultivation. Studies have shown that using a combination of *Bacillus thuringiensis* (Bt), *Helicoverpa armigera* nucleopolyhedrovirus (HaNPV), and 0.3% neem oil significantly increased tomato yields while providing the highest cost-benefit ratio among the treatments tested.

In contrast, applying neem oil, the predatory insect *Chrysoperla carnea*, or HaNPV alone was less effective, producing comparatively lower yields. These findings highlight the importance of integrating multiple eco-friendly pest management tools rather than relying on a single method to achieve optimal crop protection and profitability.

Brinjal (*Solanum melongena* L.) is an important vegetable crop in India, valued for its high returns to farmers. However, it is highly vulnerable to several insect pests, including the shoot and fruit borer (*Leucinodes orbonalis* Guenee), Hadda beetle (*Epilachna vigintioctopunctata* Fabricius)



and aphids (*Aphis gossypii* Glover) which can cause significant yield and quality losses.

Biological control in Bio-intensive IPM

Neem formulations: Commercial products such as Neemazal T/S and Neemazal-F exhibit strong antifeedant and toxic effects on sphingid larvae, leaf beetle grubs, and ash weevil adults, with Neemazal-F at 1 ml/liter being most effective.

Other plant extracts: Extracts from *Annona squamosa*, *Argemone americana*, and *Calotropis gigantea* reduce Hadda beetle populations.

Neem cake application: Applying neem cake four times during the crop cycle decreased shoot and fruit borer incidence from 40% to 8%, resulting in a 68% increase in yield.

Ash weevil management: Neem cake (500–1000 kg/ha at transplanting) or 4% neem seed kernel extract drenching effectively reduces incidence of ash weevil, which damages roots and leaves.

BIPM provides a holistic, sustainable, and farmer-friendly approach to managing brinjal pests. Integrating natural enemies, botanical pesticides, and smart cultural practices ensures higher yields, lower input costs, and environmentally safe production, making it a preferred strategy for modern brinjal cultivation.

Chilli

India is one of the largest producers of chilli (*Capsicum annuum* L.), which is an essential ingredient in Indian vegetarian and non-vegetarian cuisine. Chilli is highly valued for its pungency, and Indian recipes without it are almost unthinkable. The major pests of chilli include thrips, *Scirtothrips dorsalis* (Hood), and mites, *Polyphagotarsonemus latus* (Banks).

Chilli is attacked by several serious pests that cause significant yield losses. The major pests include thrips (*Scirtothrips dorsalis* Hood), mites (*Polyphagotarsonemus latus*

Banks), fruit borers such as *Spodoptera litura* and *Helicoverpa armigera*, along with sucking pests like aphids, jassids, and whiteflies. These pests not only reduce yield but also affect fruit quality and transmit viral diseases.

Bio-intensive IPM in Chilli

Bio-intensive pest management (BIPM) in chilli involves the integration of host plant resistance, cultural, biological, botanical, and need-based chemical control measures to manage pests sustainably. Tolerant varieties such as HC-144 (against whitefly and aphid) and G-5 (also known as Andra Jyothi), K-2, and X-235 (also called Bhaskar) (against thrips) are used as the first line of defence. Cultural practices include raising seedlings under white nylon nets, maintaining field sanitation by removing infested plant parts, and adopting timely sowing with balanced fertilization.

Biological control focuses on the conservation of natural enemies like *Encarsia guadeloupae* and *E. haitiensis* for whitefly management and the release of *Trichogramma chilonis* @ 2.5 lakh ha⁻¹ against fruit borers. Botanical and biopesticides such as neem-based formulations and microbial insecticides are employed to suppress sucking pests and early pest stages. When pest populations exceed the economic threshold level, need-based application of safer chemical molecules such as root dipping of seedlings in imidacloprid (0.2%) before transplanting and selective insecticides like thiacloprid, fenpyroximate, and diafenthiuron is recommended. This integrated approach minimizes pesticide residues, conserves natural enemies, and ensures sustainable chilli production.

Malvaceous Crops

Importance of Okra

Okra (*Abelmoschus esculentus* (L.) Moench) is the most economically important vegeta-



ble crop among malvaceous crops. It is widely cultivated in India and contributes significantly to farmers' income.

Major Insect Pests of Okra

The major insect pests of okra include the leafhopper *Amrasca biguttula biguttula* (Ishida), whitefly *Bemisia tabaci* (Gennadius), which acts as a vector of yellow vein mosaic disease, and shoot and fruit borers *Earias insulana* (Boisduval) and *Earias vitella* (Fabricius). These pests cause severe yield losses and adversely affect fruit quality.

Bio-intensive IPM in Okra

Bio-intensive integrated pest management (IPM) in okra involves the use of host plant resistance, conservation of natural enemies, microbial agents, botanicals, and need-based chemical control. Tolerant varieties such as Punjab-7, Clemson Spineless, MP-7, and AE-57 show resistance to *Earias vitella*, while New Selection and Punjab Padmini are tolerant to *Amrasca kerri*; varieties like Parbhani Kranti, Varsha Uphar, Arka Anamika, IC-7194, and IC-13999 are resistant to yellow vein mosaic disease.

Conservation of parasitoids such as *Erythmelus empoascae*, *Stethymium empoascae*, *Bracon hebetor*, and *Microbracon lefroyi*, along with predators like coccinellids and spiders, is essential. Microbial agents such as *Beauveria bassiana* and *Bacillus thuringiensis* is effectively control whiteflies and *Earias* spp.

Botanical insecticides, including 3% leaf extract of *Parthenium hysterophorus*, are effective against leafhoppers without harming beneficial insects. Integration of microbial agents with reduced doses of insecticides, provides effective and sustainable control of okra pests.

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Nutrient Management in Natural Farming and Their Sources

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Introduction

Natural farming is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects (IFOAM, 2013). In these production system Organic products are grown under a system of agriculture without the use of chemical fertilizers and pesticides with an environmentally and socially responsible approach. It preserves the reproductive and regenerative capacity of the soil, good plant nutrition, and sound soil management, produces nutritious food rich in vitality which has resistance to diseases (APEDA, 2015).

Nutrient management under natural farming

Although nutrient management in natural farming is fundamentally different to soils managed conventionally. The same nutrient cycling processes operate in naturally farmed soils as those that are farmed non-naturally although their relative rates and Importance may differ. Application of organic sources such as manure, compost and green manures to supply nutrients and maintain soil organic matter.

Soil degradation: is the major obstacle for sustainability of crop production and human survival. With deteriorating climate change effects, of erratic rainfall patterns, sudden increase in rainfall intensity and temperature fluctuation around the world is a serious challenge for farmers, environmentalists and common man.

Soil health improvement: is pre-requisite for sustaining soil health and crop productivity. Agricultural management

practices can reduce delivery of normal ecosystem services and functions, for instance by intensive use of chemical fertilizers and pesticides can increase nutrient losses, polluting water bodies (eutrophication) and aquatic organisms.

Nutrient sources under natural farming

Manure: Manure application is often valuable to organic production. The nutrient composition of manures varies with type of animal, quality and quantity of bedding material, feed composition, storage conditions and length of storage.

Compost: Composting converts organic waste into material of higher nutrient concentration, and reduces the bulk of organic materials through decomposition, therefore it is often easier to handle than the bulk organic material. Apart from nutrient management composting is also recommended in organic farming as a useful tool for controlling weeds, diseases and pests.



Green Manuring: Green manuring is growing in the field plants usually belonging to leguminous family and incorporating into the soil after sufficient growth. The plants that are grown for green manure known as green manure crops. The most important green manure crops are sunnhemp, dhaincha, pillipesara, clusterbeans and Sesbaniastrata.

Cover crops: Cover crops can improve soil physical properties, and soil microbial activity. Well-grown cover and catch crops can retain nitrogen that might otherwise be lost by volatilization, runoff, or leaching and also provide a source of fresh organic matter.

Crop rotation: Crop rotation can contribute to improved soil physical properties, nutrient availability, pest management, crop yield and nutrient use efficiency.

Develop crop rotations that include legumes as a source of nitrogen, disturbance to environmental systems. Many ecological interventions have been addressed to improve the delivery of ecosystem services and functions, by reducing anthropogenic inputs in agriculture.

Soil Health

Soil health is defined as the capacity to perform various functions to support plants and organisms. Recovery, restoration and conservation of soil health is utmost important for survival of living beings. Reviving soil health with use of soil organic amendments is gaining much attention due to its cost-effective and eco-friendly approaches. Soil amendments influence on physical-chemical and biological properties of soil.

Types of soil amendments

The most preferred soil amendments include natural minerals like gypsum, pyrite, lime; other amendments from biological origin such as animal manures, compost, vermicompost, farm yard

manure etc., are organic in nature. Commonly used soil amendments in agriculture: Some of the commonly used organic amendments/ manure used in agriculture are described as follows.

- Animal manures
- Composting
- Vermicompost
- Crop residues
- Biofertilizers
- Biochar
- Municipal solid waste (MSW)
- Organic wastes from agro-industries:

Other organic amendments: Other amendments such as coir pith, seri-waste, tank silt etc. are available as location specific materials for agriculture usage.

Inorganic amendments: In oilseed crops gypsum, pyrite etc. are the common soil amendments used due to high S demand, which influence crop yield by 10– 48% in irrigated and 25–124% under dryland conditions.

Chemical properties: Combined use of organic amendments such as FYM, compost, vermicompost, green manures etc. with chemical fertilizers are essentially required to improve soil health.

Biological properties: Soil microbes are crucial components for sustaining soil health as they have an affirmative role in enhancing nutrients availability by nutrient cycling through the processes of mineralization and immobilization. Addition of organic amendments improve biological properties by stimulating microbial growth, energy, nutrients, indirectly promoting crop growth and development.

Conclusions

Nutrient management in naturally managed fields is fundamentally different to soils managed conventionally which requires a long-term planning and a combination of cultural practices and inputs. Although there are an increasing



number of commercially available organic fertilisers and bio fertilizers, the most profitable organic farms often source nutrients on or near the farm by employing organic wastes, scavenging residual soil nutrients, and nitrogen fixation through biological means.

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Persimmon Fruit Tree: The Golden Gem of Autumn Orchards

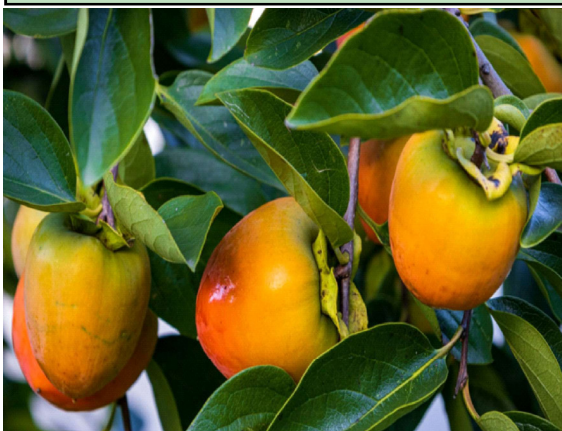
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Introduction

When autumn arrives and many fruit trees begin to fade, the persimmon fruit tree steps into the spotlight. With its glowing orange fruits, glossy green leaves, and sweet, honey-like flavor, the persimmon has earned a place among the world's most cherished fruit trees. Revered for centuries in Asia and increasingly popular across Europe and the Americas, the persimmon is both a nutritional powerhouse and an ornamental delight. The persimmon fruit tree is admired not only for its delicious fruit but also for its fascinating reproductive biology and dependable productivity. From delicate spring blossoms to vibrant autumn fruits, the persimmon follows a well-defined seasonal rhythm that makes it both agriculturally valuable and visually striking.



The genus *Diospyros*, a name derived from Greek meaning "fruit of the gods." This poetic title hints at the fruit's long-standing cultural and culinary importance. Persimmons are native primarily to China, where they have been cultivated for over 2,000 years, but they are also deeply rooted in Japan, Korea, and parts of Southeast Asia.

Today, persimmons are grown worldwide in temperate and subtropical regions, admired not only for their fruit but also for

their attractive form and seasonal beauty.

Persimmon trees belong to the genus *Diospyros* (family Ebenaceae). They are deciduous, slow- to medium-growing trees that can reach 5–15 meters in height, depending on species and growing conditions. The trees are long-lived and may continue bearing fruit for several decades.

Results

There are several species of persimmon, but three are most commonly cultivated:

- **Asian or Japanese Persimmon (*Diospyros kaki*)** The most widely grown species, producing large, sweet fruits. These are further divided into:
 - *Astringent varieties* (e.g., 'Hachiya'), which must be fully ripe before eating
 - *Non-astringent varieties* (e.g., 'Fuyu'), which can be eaten while still firm
- **American Persimmon (*Diospyros virginiana*)** Native to North America, with smaller but intensely flavorful fruits, often used in baking and preserves.



- **Black Persimmon (*Diospyros digyna*)**

Less common, known for its dark flesh and unique taste.

Persimmons offer a rich, sweet flavor, often described as a blend of honey, apricot, and pumpkin. Ripe fruits can be eaten fresh, scooped with a spoon, or sliced into salads.

In many cultures, persimmons are also:

- Dried naturally in the sun
- Used in desserts, puddings, cakes, and breads
- Made into jams, syrups, or fermented products

In East Asia, dried persimmons are considered a seasonal delicacy and a symbol of abundance and good fortune.

Persimmons are as healthy as they are delicious. They are rich in:

- **Vitamin A:** supports vision and immune health
- **Vitamin C:** boosts immunity and skin health
- **Dietary fiber:** aids digestion and heart health
- **Antioxidants** such as flavonoids and carotenoids, which help combat oxidative stress

Regular consumption of persimmons has been associated with improved digestion, reduced inflammation, and better cardiovascular health.

Persimmon trees are relatively low-maintenance, making them suitable for home gardeners.

Growing conditions include

- Full sun exposure
- Well-drained soil
- Moderate watering once established

Persimmon trees typically flower in late spring to early summer, after the risk of frost has passed. This late flowering habit is advantageous, as it reduces flower damage from spring frosts compared to many other fruit trees.

Persimmons exhibit complex sexual expres-

ssion, which varies by species and cultivar:

- **Male flowers:** Small, usually borne in clusters, producing pollen
- **Female flowers:** Larger, solitary, with a well-developed ovary
- **Perfect (bisexual) flowers:** Contain both male and female parts

Some cultivars bear only female flowers and can produce fruit parthenocarpically (without pollination), resulting in seedless fruits. Others require pollination for optimal fruit set and seed development.

Pollination is mainly carried out by insects, especially bees. While many commercial varieties set fruit without pollination, cross-pollination can:

- Increase fruit size
- Improve shape
- Enhance yield stability in some cultivars

After successful flowering, fruit development proceeds slowly through the summer and accelerates as temperatures cool in early autumn. Persimmons typically mature in late autumn, often after leaf fall.

Persimmon fruits vary widely depending on cultivar

- Shapes: round, oblate, conical, or heart-shaped
- Size: 50–300 g per fruit

Asian persimmons (*Diospyros kaki*) generally produce larger fruits than American persimmons (*Diospyros virginiana*).

- Skin color: Yellow-orange to deep reddish-orange at maturity
- Flesh texture:
 - o Firm and crisp (non-astringent types like 'Fuyu')
 - o Soft and jelly-like when ripe (astringent types like 'Hachiya')

Astringency is caused by soluble tannins

- Astringent cultivars must be fully ripe before consumption
- Non-astringent cultivars can be eaten while still firm

As the fruit ripens, tannins become



insoluble, eliminating the puckering sensation.

Seed number varies

- Seedless fruits are common in unpollinated flowers

- Pollinated fruits may contain 1–8 seeds, often darker-fleshed around the seed cavity

Persimmon trees typically begin bearing fruit 3–6 years after planting, full commercial production is usually reached after 8–10 years

Yield depends on cultivar, climate, and orchard management:

- Young trees: 10–25 kg per tree
- Mature trees: 50–150 kg per tree per season
- Under optimal conditions, some Asian cultivars may exceed 200 kg per tree

Persimmons bear fruit on current season's shoots that arise from one-year-old wood. This makes annual pruning important to encourage new growth and maintain productivity.

Natural fruit drop may occur in early summer due to

- Excess fruit load
- Water stress
- Nutrient imbalance

Controlled thinning can improve fruit size and quality.

Persimmons are harvested when they reach full size and characteristic color

- Non-astringent types are harvested firm
- Astringent types are often harvested firm and ripened off the tree

The fruit has good shelf life and can be stored for several weeks under cool conditions. Some varieties are well suited for drying and processing.

Most persimmon trees are resistant to pests and diseases and can tolerate short periods of drought. They also have excellent ornamental value, with bright fruits often

remaining on bare branches after leaf fall—creating a striking winter landscape.

In many cultures, the persimmon symbolizes longevity, prosperity, and transformation. In Japan and China, persimmon trees are often planted near homes as a sign of good luck. In folklore, the fruit is associated with patience—especially with astringent varieties that require time to fully ripen.

Conclusion

The persimmon fruit tree is truly a tree for all seasons—offering beauty, nutrition, and cultural richness. Whether enjoyed fresh, dried, or baked into traditional recipes, persimmons connect people to centuries of agricultural heritage. As interest in diverse and nutritious fruits grows, the persimmon continues to shine as a golden treasure of the orchard. The persimmon fruit tree combines unique flowering biology, diverse fruit characteristics, and reliable yields, making it an excellent choice for both commercial orchards and home gardens. Its late flowering, attractive fruits, and flexible pollination behavior contribute to stable production even under varied climatic conditions. As global interest in nutritious and specialty fruits grows, the persimmon continues to gain recognition as a valuable and resilient fruit crop.

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Beyond Prices and Yields: Behavioural Economics in Indian Agriculture

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Introduction

Indian agriculture is often analysed in the prism of prices, yields, costs and government support or subsidy mechanisms. Classical Agricultural Economics assumes that farmers respond rationally to these incentives, as it is built over the broader framework of mainstream economics. However, farming decisions in India are shaped by monsoon uncertainty, small landholdings, social structures and intergenerational transfer of practices. Under such conditions, farmers' behaviour is influenced not only by economic returns but also by recognisable patterns in their psychology, habit, risk perception and prevailing social norms. Behavioural Economics helps to explain these patterns and provide deeper insights into how farmers actually make decisions.

Understanding Behavioural Economics in the Indian Context

Behavioural Economics integrates psychology with Economics to explain systematic deviations from rational behaviour or to explain rationality. In Indian fabric, where farming is both a livelihood as well as cultural identity - rather than a purely commercial activity, behavioural factors strongly influence the decision-making process regarding crop choices, technology adoptions, insurance participations and traditional practices. This thought process is shaped by past experiences, peer influence, reliance on institutions and perceived risks, rather than only expected profits or a higher benefit-cost ratio.

Loss Aversion and Technology Adoption

Loss aversion is a behavioural bias where the pain from a loss is psychologically more

intense than the pleasure from an equivalent gain. It is a dominant behavioural trait among Indian farmers: they tend to avoid choices that may lead to losses, even if potential gains are high. In Punjab and Haryana, despite awareness of water scarcity, many farmers continue paddy cultivation because it is perceived as a 'safe' crop, due to strong institutional backing and MSP guarantee. Even when alternatives like maize, pulses or horticultural crops promise comparably higher returns, they are discouraged due to fear of market uncertainty or non-adoptive patterns. This loss-averse behaviour explains the slow diffusion of crop diversification initiatives in various regions of the country, strengthening the habit of continuing the existing cropping more intensely and discouraging any newer adoption.



Risk Perception in Rainfed Agriculture

Risk perception in rainfed agriculture refers to how farmers subjectively understand and respond to uncertainties arising from rainfall, yields and income, rather than the statistically calculated level of risk: the true estimation of risk. Rainfed agriculture is heavily monsoon-dependent. Arrival of Monsoon is highly variable and unpredictable. Farmers take their decisions based on recent experiences, such as the previous season's drought or recent crop failure, rather than long-term averages of climatic parameters or scientific forecasts.

As a result, after a drought year, farmers may reduce fertilizer application, avoid credit or shift to low-input crops even when rainfall conditions improve. Conversely, a few consecutive good monsoon years may create overconfidence, encouraging farmers to expand cultivation area and adopt high water footprint crops. This behavioural pattern shows that farmers' decisions are guided more by perceived risk - shaped by experience and memory, than by understanding of objective probability. Behavioural economics highlights this gap between actual risk and perceived risk, which strongly influences input use, technology adoption and income stability in rainfed agriculture.

Status Quo Bias and Cropping Patterns

Status quo bias is a cognitive bias referring to people's disproportionate preference for the current situation ('status quo'), even when superior alternatives are readily available. Still, they are rejected and the ongoing condition prevails. The resistance to change drives a tendency to stick with known options, doing nothing and discouraging to choose a new path. Status quo bias is clearly visible in Indian cropping systems. In Punjab, long-established rice-wheat monoculture causes severe groundwater depletion. In rainfed tribal

belts of central India, farmers continue traditional low-input cropping systems even when improved varieties are available. Familiarity and inherited knowledge often even outweigh economic calculations.

Social Norms and Peer Influence in Villages

Farming decisions in India are strongly influenced by village-level social norms, which are mostly informal and intergenerationally transferred. In rural areas, farming is not an individual activity carried out in isolation; rather, it is a collective enterprise. Farmers often look to progressive farmers before adopting new seeds, technologies or practices. In tribal belts of Odisha and Chhattisgarh, adoption of improved seeds or line sowing has been higher where community demonstrations were conducted. If influential farmers successfully adopt a practice, others are more likely to follow, believing it to be safe and socially acceptable. Conversely, if a practice is viewed negatively or rejected by the community, farmers hesitate to adopt it even when it is economically beneficial or ecofriendly. Fear of social criticism discourages experimentation. This peer-driven behaviour explains why demonstration plots, farmer field schools and farmer-to-farmer extension are highly effective. Behavioural patterns coupled with social approval often matter as much as prices or profits can shape agricultural decisions.

Present Bias and Sustainability Investments

Present bias refers to the psychological tendency to give greater importance to immediate costs and benefits and undervaluing future gains. In agriculture, many investments such as soil conservation, agroforestry, organic matter improvement, micro-irrigation or climate-resilient practices involve upfront costs, while their benefits are realized only after several



seasons or years. Because of present bias, farmers may postpone or avoid these investments, even when they are economically profitable in the long run. Immediate financial pressures, such as household expenses, debt repayment, or input purchases for the current season, dominate decision-making. As a result, short-term survival takes priority over long-term sustainability. The same pattern is visible in Punjab, where higher chemical application and free or subsidised groundwater irrigation were employed for increasing yield, which damages the environmental sustainability and harms the ecosystem. Employing approaches of Behavioural Economics, present bias can explain why farmers often underinvest in cropping practices that enhance soil health, water efficiency or climate resilience. Also, it highlights the need for policies reducing upfront costs in order to build long-term benefits stronger, focusing on regional sustainability. In Punjab, investments in crop residue management are often delayed due to immediate cost concerns, accelerating stubble burning. In tribal regions, agroforestry adoption remains slow because benefits accrue over many years. So everywhere farmers prioritise short-term survival over long-term resilience, due to Present bias leads.

Behavioural Aspects of Crop Insurance

The behavioural aspects of crop insurance are less debated, because crop insurance is something that is always analyzed under the purview of political lens and viewed as a subsidy-based system. Behavioural Economics explains why many farmers do not enrol in insurance schemes - even when premiums are subsidised, risks are high and payment systems are also negotiable. So, perspective-wise, this is not simply an economic issue but a sociopsychological one. Farmers often exhibit loss aversion and

avoid paying premium for a future benefit, which is highly uncertain. Many farmers also perceive insurance as an unnecessary expense (in good years) - specially in irrigated regions where chances of crop failure are very low. Although formalities, asymmetric information and limited perception of insurance terms further discourage participation.

Social norms also matter; if peers do not enrol or have negative experiences, others are less likely to join. Behavioural Economics shows that insurance uptake improves when enrolment is simple, communication is clear, benefits are framed as protection against income loss and trust is built through timely payouts and local institutional support. The practices of crop insurance schemes across India are low. In Punjab, insurance seems to be unnecessary due to guaranteed MSP. Crop insurance registration in rainfed regions is naturally low.

Conclusion

Indian agriculture is not only shaped by markets and policies but also deeply rooted behavioural patterns. From societal aspects, psychological patterns to climatic volatilities: all play key roles in determining the fabric of the Indian peasantry diaspora. Behavioural Economics reveals that farmers' decisions are influenced by loss aversion, risk perception, habits and social norms. Recognising these behavioural patterns may allow policymakers to design interventions that align with real farmer behaviour. In an era of climate change, water stress and market volatility, integrating Behavioural Economics into policy-oriented agrarian systems is essential for building resilient, inclusive and sustainable farming systems in India.

Conclusion

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Incidence of Common Surgical Affections in Cattle of Different age Groups in India

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Introduction

In India, surgical affections in cattle including buffaloes are categorized into congenital (present at birth, often inherited or developmental) and acquired (developed later due to injury, infection, or management). These conditions are highly prevalent with a higher incidence of congenital defects in male calves (0–1 month) and acquired conditions often related to trauma, management or environmental factors in adults.

Common Congenital and Aquired Affections In Cattle And Buffaloes

1. Digestive System

There are many diseases of cattle that require surgical interventions. In cattle, rumen microflora plays an important in digestion and thus restoration of normal microflora activity following surgery is indispensable. The overall incidence of the surgical affections in India [2,3,4,11] are include Atresia coli (2.3%), Atresia ani (12.5%), Rectal tears (0.3%), Rectal prolapse (4.3%), Caecal dilatation and torsion(0.1%), Volvulus (1.0%), Intussusception (1.3%), Intestinal obstruction (1.3%), Abomasal displacement (3.3%), Traumatic reticuloperitonitis (4.3%), Bloat (5.3%), eosophageal wounds and fistula (0.3%), esophageal obstruction (2.3%), Actinobacillosis (1.1%), Salivary gland trauma (0.2%) and tumors of dentature (0.3%). Among different age groups the incidence of these surgical

affections are as under Group A (calves >1year) - Aresia ani (52.3%) followed by Rectal prolapse (32%) and intestinal obstruction (12.5%) are the commonly encountered affections. Group B (Heifer 2-3 years)- Intussusception (23%), Intestinal obstruction (13%) and Abomasal displacement (8.3%). Group C (Adults 3-7 years)- Traumatic reticuloperitonitis (24.5%), Bloat (15.6%) and oesophageal obstruction (4.3%). Atresia ani & Atresia coli and tumors of dentature are congenital abnormalities whereas the rest of the affections are acquired. Surgical treatment of atresia ani through circular anal skin removal has a good prognosis for survival. Colostomy is not an acceptable treatment from the calf's perspective because of the resulting poor condition but the high survival rate is important to allow continued milk production of the dam. Early diagnosis, supportive treatment, and surgical correction are important in



management of atresia coli.

2. Respiratory and Cardiovascular System

The main function of the upper respiratory system is to deliver oxygen and to remove carbon dioxide from the lower respiratory system [9, 10]. The incidence of respiratory disorders involving upper respiratory tract (nostrils, nasal cavity, paranasal sinuses, pharynx and larynx) are less common in cattle. Mostly, upper respiratory tract disorders are due to obstructions, congenital malformations, infections and trauma caused by imprisoned foreign bodies taken along with feed. The overall incidence of the surgical affections in India is include Traumatic pericarditis (9.2%), Congenial cardiac defects (6.1%), thoracic anomalies (3.2%), Empyema of the sinus (1.8%) and Nasal cavity obstruction (0.9%). Among different age groups the incidence of these surgical affections are as under:

Group A (calves >1year)- Congenial cardiac defects (26%) is the commonly encountered affections.

Group B (Heifer 2-3 years)- Empyema of the sinus (15%) and Nasal cavity obstruction (9%).

Group C (Adults 3-7 years)- Traumatic pericarditis (22.3%)

Congenital abnormalities which are mostly encountered in calves include Ectopia cardis, patent foramen ovale, ventricular septal defects, secondary right ventricular hypertrophy and patent ductus arterious.

Ectopia cordis is a congenital heart disease wherein the heart is located outside of instead of within the pleural cavity. This disease is classified into 3 types on the basis of the location of the heart – cervical, thoracic, and abdominal.

3. Urinary System

Indications for surgery of the urinary system in cattle are relatively few. Apart from traumatic injuries, a surgical intervention is mostly indicated in cases of obstructive urolithiasis. The overall incidence

of the surgical affections in India [2] is including obstructive urolithiasis (12%), Previous urachus (4%) and Hypospadias and urethral diverticulum (0.8%). Among different age groups the incidence of these surgical affections are as under.

Group A (calves >1year)- Obstructive urolithiasis (36%) followed by Previous urachus (12%) and Hypospadias and urethral diverticulum (5%) are commonly encountered.

is the commonly encountered affections.

Group B (Heifer 2-3 years) and **Group C** (Adults 3-7 years)- In both the groups Obstructive urolthiaisis (11%) is the common surgical entity.

Previous urachus, Hypospadias and urethral diverticulum are congenital abnormalities.

Patent urachus is a common condition in calves which is frequently associated with omphalitis. A membranous urethral diaphragm prevented closure of the urachus in a female calf. The patent urachus was complicated by an ascending infection of the intraabdominal umbilical remnants.

4. Genital System

Female genital system in cattle is generally an emergency operation either during late gestation or around parturition. Exceptions include occasional ovarian tumors necessitating ovariectomy or draining out a vaginal abscess. The overall incidence of the surgical affections in India are include Uterine torsion (9.8%), Uterine prolapse (9.6%), vaginal prolapse (7.8%), rupture of prepubic tendon (2.1%). In males, Haematoma of penis (4.1%), Phimosis and Paraphimosis (1.2%) and Ectopic testes (0.2%). Among different age groups the incidence of these surgical affections are as under **Group A** (calves >1year)-Ectopic testes (22%) is commonly encountered. **Group C** (Adults 3-7 years)- Uterine torsion (21.2%), Uterine prolapse (19.6%), Vaginal prolapse (9.8%). Prolapse of the uterus may occur in any



species; however, it is most common in dairy and beef cows and ewes and less frequent in sows. It is rare in mares, bitches, queens, and rabbits. Invagination of the tip of the uterus, excessive traction to relieve dystocia or retained fetal membranes, uterine atony, hypocalcemia, and lack of exercise have all been incriminated as contributory causes. Prolapse of the uterus invariably occurs immediately after or within several hours of parturition, when the cervix is open and the uterus lacks tone. Prolapse of the postgravid uterine horn usually is complete in cows, and the mass of uterus usually hangs below the hocks. The invagination of the contralateral horn, which is prevented from exteriorization by the strong intercornual ligament, can be located by careful examination of the surface of the prolapsed organ. In sows, one horn may become everted while unborn piglets in the other prevent further prolapse.

5. Muscular-skeletal System

Skeletal muscles consist of bundles of striated muscle fibers which contract in length and create a pulling force on the bone through tendons, bringing about movements at the joints. Muscles have very good blood supply and heal rapidly under normal circumstances. The overall incidence of the surgical affections in India [2,5,6] are include Upward fixation of patella (7.3%), Knuckling (4.3%), Chondrodysplasia syndrome (1.8%), Dislocation (1.8%) and Fractures (0.9%). Among different age groups the incidence of these surgical affections are as under Group A (calves >1year)- Knuckling (13%), Chondrodysplasia syndrome (12%) is commonly encountered. Group B (Heifer 2-3 years)- Fractures (29%) and Dislocation (12%) Group C (Adults 3-7 years)- Upward fixation of patella (34%), Fractures (22%) and Dislocation (9.4%).

The treatment of long bone fractures in newborn calves remains difficult because

of a high incidence of complications. These are most likely attributable to trauma during delivery, which results in insufficient colostrum intake and predisposes to concurrent diseases. In addition, the characteristics of juvenile bones do not provide sufficient physical strength for implants. Therefore, professional and diligent assistance during forced extraction, particularly in presentations with "stifle lock" or "hip lock", is required to minimize the incidence of long bone fractures in newborn calves. Most cases require surgical fixation, which is time consuming, expensive and carries a guarded prognosis.

6. Nervous system

It is difficult to draw a line between a medical and a surgical case when involvement of the nervous system is concerned [18]. The overall incidence of the surgical affections in India [2] is including Hydrocephalus (0.5%), Meningocele (0.3%) and Gid (0.1%). Among different age groups the incidence of these surgical affections are as under

Group A (calves >1year)- Hydrocephalus (11%) and Meningocele (6%) is commonly encountered.

Hydrocephalus, an increase in volume of the CSF, can appear similar to hydranencephaly, but in hydrocephalus the ventricles retain a complete ependymal lining. Clinical signs can vary from mild to severe and include seizures, lethargy, or other forebrain abnormalities. There may be extensive expansion of the lateral ventricles in the frontal lobes. Hydrocephalus is seen sporadically in all large animals, although it is relatively common in calves, in which inheritance and vitamin A deficiency have been implicated.

7. Special Sense organs

Importance of special sense organs (eyes and ears) needs no emphasis. Economic losses due to affections of eye and ear are enormous. The overall incidence of the surgical affections



in India [2,17] are include Orbital injuries (0.9%), Eye lid trauma (0.6%), Dermoid (0.4%), Ocular tumors (0.3%) and Aural hamatoma (0.3%). Among different age groups the incidence of these surgical affections are as under Group A (calves >1year)- Dermoid (16%) and Aural hamatoma (9%) are commonly encountered. Group B and C – Ocular tumors (23%), Dermoid (12%) and Orbital injuries (9.4%).

8. Neoplasm's

Neoplasm growth exceeds uncontrolled in comparison to the normal tissue and persists in the same excess even after cessation of the stimuli which evoked the change. The overall incidence of the surgical affections in India [8,16] are include Papilloma (0.4%), Squamous cell carcinoma of horn (0.2%) and eye (0.1%) and Osteosarcoma (0.01%). Among different age groups the incidence of these surgical affections are as under Group B and C – Papilloma (13%) and Squamous cell carcinoma of horn (7%) and eye (3.6%).

9. Mammary Glands

Mammary glands are modified skin glands, rudimentary in males but functional in the females. In cattle, the mammary glands consist of four quarters. Diagnosis of the teat and udder diseases is mostly based on critical inspection, palpation and probing [15]. The overall incidence of the surgical affections in India are include Gangrenous mastitis (9.8%), Membranous obstruction of teat (7.4%), Papilloma or warts (5.8%), Teat laceration (3.2%) and Supernumerary teats (0.7%). Among different age groups the incidence of these surgical affections are as under: Group B and C – Gangrenous mastitis (43%), Teat membranous obstruction (12%) and Teat laceration (8.2%).

10. Integumentary System

The skin in its bulk form forms the largest organ of the body. Most common affections of the skin are various kinds of wounds and their complications. Due to pigmentation

and tough skin, many inflammatory lesions are not noticed until infected secondarily [14]. The overall incidence of the surgical affections in India is including Abscess (33.8%), Cyst (21%) and Haematoma (11.1%). Among different age groups the incidence of these surgical affections are as under: Group A (calves >1year) - Abscess (40.1%) and Cyst (9.6%) are found in this group. Group B and C – Abscess (19.3%) and Haematoma (8.3%).

11. Hernias

Congenital and acquired hernias are common in cattle of all age groups. Congenital hernias may occur due to anatomical variations, polygenic inheritance or infectious diseases [12,13]. The primary predisposing cause of acquired hernia is mostly trauma. Other factors may act as exciting cause e.g., increased intra-abdominal pressure. The overall incidence of the surgical affections in India is including Umbilical hernia (7.3%), Lateral abdominal hernia (3.2%) and Diaphragmatic hernia (0.9%). Among different age groups the incidence of these surgical affections are as under: Group A (calves >1year) - Umbilical hernia (54.1%) is the more common type of hernia encountered. Group B and C – Lateral abdominal hernia (12%) and Diaphragmatic hernia (5.1%).

Conclusions

Based on clinical studies in India, congenital and acquired surgical affections are significant contributors to morbidity and economic losses in cattle particularly impacting neonatal calves and high yielding dairy cattle. Congenital defects are more frequently reported in male calves (0-1 month) and often involve the gastrointestinal and umbilical regions, while acquired conditions are common in adult cows, focusing on the mammary system, feet and reproductive organs.





Jeevamrit and Panchgavya: Impact on Sustainable Vegetable Production

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Introduction

Vegetable production plays a vital role in ensuring nutritional security, income generation and employment opportunities in India. However, excessive use of chemical or inorganic fertilizers and pesticides over the few decades has led to serious problems such as soil degradation, decline in microbial activity, environmental pollution and health hazards. These concerns have increased interest in sustainable and organic farming and natural farming practices that maintain soil health while ensuring stable yields. Among various organic liquid formulations used in natural farming, jeevamrit and panchgavya have majorly gained attention due to its low cost of preparation, ease of preparation and effectiveness in enhancing crop growth and productivity. Both formulations jeevamrit and panchgavya are based on indigenous cow (Desi Cow) products and are rich in beneficial microorganisms, nutrients, growth-promoting substances and enzymes. Application of these formulations in vegetable crops has resulted in improved plant growth, yield and quality while maintaining soil fertility.

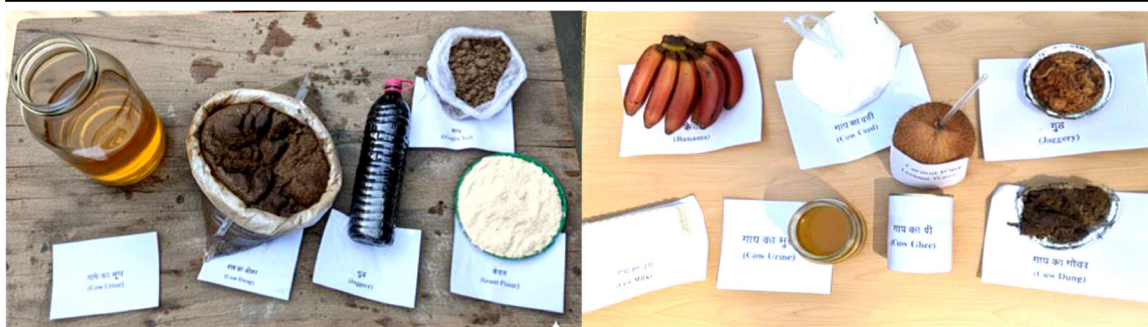


Fig.1.: Ingredients requirements for preparation of jeevamrit and panchgavya

Jeevamrit

Jeevamrit is a fermented organic fertilizer rich in microbial culture prepared by using cow dung, cow urine, jaggery, pulse flour, soil and water. Jeevamrit is made from two words 'Jeevan' means 'Life' and 'Amrit' means 'Medicine Portion'. It acts primarily

as a bio-enhancer which stimulates the microbial activity in the soil rather than supplying nutrients directly. It improves nutrient availability by activating beneficial soil microorganisms that convert unavailable nutrients into available forms for plants. It is commonly applied in vegetables



such as tomato, brinjal, chilli, okra, cabbage, cauliflower and cucurbits.

Preparation Method of Jeevamrit

Ingredients

Component	Quantity
Cow dung	10 Kg
Cow Urine	10 L
Jaggery	1 Kg
Gram Flour	1 Kg
Virgin Soil	200-300 g
Water	200 L

Procedure

1. Take a plastic container of 200 L and mix cow dung thoroughly with cow urine.
2. Add water and stir well.
3. Dissolve jaggery separately in water and then add to the mixture.
4. Add pulse flour and virgin soil from root zone of peepal or banyan tree.
5. Stir the mixture clockwise and anticlockwise for 5-10 minutes.
6. Cover loosely with a cloth and allow for fermentation in shade.
7. Stir the mixture twice daily.
8. Formulation will be ready in 5-6 days for use.

Application of Jeevamrit

- For soil application use 200-400 L/acre jeevamrit incorporated with irrigation water.
- For drip irrigation use 100-200 L/acre.
- Apply at the interval of 15-20 days especially during the phase of vegetative growth.

Benefits of Jeevamrit in Vegetable Production

Jeevamrit enhances soil microbial population by stimulating the beneficial bacteria, fungi and actinomycetes that improve nutrient cycling. It enhances the availability of nitrogen, phosphorus, potassium and micronutrients in soil. It also improves soil structure. Researches shown that regular

application of jeevamrit has increased organic matter content and soil aggregation. Active microbial activity leads to better root development and nutrient uptake. It is prepared using locally available materials, reducing dependence on chemical fertilizers. The use of jeevamrit in vegetable crops such as tomato, brinjal, chilli, okra, capsicum and bell pepper has enhanced the overall yield and quality of these vegetables. It also offers the pesticide free vegetables for the peoples.

Panchgavya

Panchgavya is a traditional organic formulation prepared by using five major desi cow products namely milk, curd, ghee, urine and dung. It also includes other natural additives like jaggery, banana and tender coconut water to enhance fermentation. Panchgavya acts as a plant growth promoter, supplying nutrients, hormones, vitamins and beneficial microbes directly to plants.

Preparation Method of Panchgavya

Ingredients

Component	Quantity
Cow dung	7 Kg
Cow Urine	10 L
Cow Ghee	1 Kg
Cow Milk	3 L
Cow Curd	2 Kg
Jaggery	3 Kg
Ripe Banana	1 dozen
Tender Coconut water	3 L
Water	10 L

Procedure

1. Take a plastic container or earthen pot mix cow dung and ghee thoroughly.
2. Keep the mixture for 3 days for fermentation.
3. Stir the mixture clockwise and anticlockwise twice daily.
4. On 3rd day add cow urine, milk, curd, jaggery, mashed bananas, coconut water



and water.

5. Cover with gunny bag and allow fermentation for 15-20 days.

6. Stir the mixture clockwise and anticlockwise twice daily.

7. Filter the formulation before use.

Application of Panchgavya

- For foliar spray use 3-5 % concentration (mix 30-50 ml/L of water).

- For soil application use 50-100 L/acre panchgavya incorporated with irrigation water.

- For seed/seedling treatment use 3% solution and treat for 20-30 minutes.

- Apply at the interval of 10-15 days especially during the phase of vegetative growth and flowering stage.

Benefits of Panchgavya in Vegetable Production

Panchgavya contains natural growth hormones such as auxin, gibberellin and cytokinin which stimulates plant growth. Foliar application of 3-5% panchgavya improves flower retention and fruit set in vegetables. It has been reported that its application increases fruit size, colour, taste and shelf life. Panchgavya contains plenty of beneficial microbes and bioactive compounds which suppress pests and diseases. The use of panchgavya in vegetable crops such as tomato, brinjal, chilli, okra, capsicum and bell pepper has enhanced the overall yield, disease tolerance and quality of these vegetables. It also offers the pesticide free vegetables for the peoples.

Combined Effect of Jeevamrit and Panchgavya

The combined use of Jeevamrit (soil application) and Panchgavya (foliar spray) has shown synergistic effects in vegetable crops. Jeevamrit improves soil health and nutrient availability, while Panchgavya directly enhances plant growth and

productivity. Together, they reduce the need for synthetic fertilizers and pesticides, making vegetable cultivation more sustainable and eco-friendlier.

Conclusion

Jeevamrit and Panchgavya both are powerful organic inputs that play a significant role in sustainable vegetable production. Jeevamrit primarily enhances soil biological activity and nutrient availability, while Panchgavya acts as a growth promoter improving plant vigor, yield and quality. Their regular use not only reduces the cost of cultivation but also restores soil fertility and environmental health. Adoption of these indigenous organic formulations can help farmers achieve higher productivity in vegetables while ensuring long-term sustainability and food safety.

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Sowing Sustainability: A Deep Dive into India's National Mission on Natural Farming

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Introduction

In a bold move towards sustainable agriculture, the Government of India has placed a significant bet on Natural Farming as a solution to multiple challenges: rising input costs, deteriorating soil health, and the escalating climate crisis. Central to this initiative is the National Mission on Natural Farming (NMNF), a transformative program designed to wean Indian agriculture away from chemical-intensive practices and towards a more holistic, economically viable, and eco-friendly system.

This article explores the mission, vision, intricate framework, and real-world impact through case studies of this national programme.

Mission and Vision: The Core Philosophy

Vision: To transform agriculture in India by establishing a nationwide movement of sustainable and climate-resilient Natural Farming, ensuring prosperity for farmers, well-being for consumers, and harmony with nature.

Mission: To promote and propagate Natural Farming among the nation's farmers through a systematic approach involving capacity building, extensive handholding, creation of value chains, and public awareness. The mission aims to make farming a low-cost, high-return enterprise that enhances soil fertility, conserves water, and produces safe and nutritious food.

The Guiding Principle: What is Zero Budget Natural Farming (ZBNF)?

While the national mission uses the broader term "Natural Farming," its foundation is deeply rooted in the principles of Zero Budget Natural Farming (ZBNF), popularized by agriculturist Subhash Palekar. The "Zero Budget" refers to the aspiration of eliminating the need for credit to purchase external inputs, thereby reducing debt.

The four key pillars of ZBNF are:

- 1. Bijamrita:** Treatment of seeds using local cow dung and urine-based formulations.
- 2. Jiwamrita:** Application of a fermented microbial culture to the soil to enhance fertility.
- 3. Mulching:** Protecting the topsoil with organic matter.
- 4. Waaphasa:** Ensuring soil aeration.

Schemes and Government Initiatives

The promotion of Natural Farming is



primarily channelled through:

- **Bhartiya Prakritik Krishi Paddhati (BPKP):** A sub-scheme under Paramparagat Krishi Vikas Yojana (PKVY), providing financial assistance for clusters and handholding.

- **National Mission for Sustainable Agriculture (NMSA):** Supports aligned components like soil health management.

- **State-Specific Schemes:** Such as Andhra Pradesh's APCNF, Uttar Pradesh's Natural Farming Mission, and Himachal Pradesh's PrakritikKheti Khushhal Kisan Yojana.

The Governance Framework: A Multi-Tiered Structure

- **National Steering Body (NSB):** Apex strategic body chaired by the Chief Minister of a prominent Natural Farming state.

- **National Executive Committee (NEC):** Executive arm headed by the Secretary of the Department of Agriculture and Farmers' Welfare.

- **State Level Organisation:** Includes a State Apex Committee and a State Project Director for on-ground implementation.

The true test of any national programme lies in its impact on the ground. The following case studies from different states demonstrate the tangible benefits and challenges of adopting Natural Farming.

Case Study 1: Andhra Pradesh Community Managed Natural Farming (APCNF) - A Large-Scale Transformation

Background: APCNF is arguably the world's largest agroecology program and serves as a model for the national mission. It is implemented by the Rythu Sadhikara Samstha (RySS) and aims to cover all six million farmers in the state.

Implementation Model:

- **Community-Driven Approach:** The program is built around Farmer Household Groups and Women Self-Help Groups, creating a strong peer-to-peer learning and support system.

- **Capacity Building:** A massive network of Community Resource Persons (CRPs)-farmers who are master practitioners-train and handhold fellow farmers.

- **Focus on Women:** The program actively empowers women farmers, recognizing their crucial role in agriculture.

Impact & Findings:

- **Economic Resilience:** A 2021 study by the University of Reading, UK, and the Government of Andhra Pradesh found that NF farmers experienced 90% higher net incomes due to a dramatic reduction in input costs (up to 50% in some cases).

- **Yield Stability:** While yields for some commercial crops initially dipped, they stabilized and often showed increased resilience during droughts. Yields for many food crops like millets and pulses increased.

- **Dietary Diversity:** NF farmers were found to have more diverse crop patterns, leading to improved household nutrition. A study published in The Lancet Planetary Health (2023) confirmed these benefits.

Key Takeaway: APCNF proves that a state-led, community-managed model can scale up Natural Farming effectively, delivering significant economic and ecological benefits.

Case Study 2: The Tribal Farmer of Odisha - Empowerment and Food Security

Background: In the tribal-dominated districts of Odisha like Kandhamal and Mayurbhanj, farmers traditionally practiced rain-fed subsistence agriculture. Under the BPKP scheme, clusters were formed to promote ZBNF.

Farmer Profile: Sashi Murmu, a smallholder farmer from Mayurbhanj, owned 2 acres of land growing primarily paddy and vegetables.

Journey and Challenges:

- Sashi was initially skeptical, as purchasing fertilizers and pesticides with credit was



the norm, despite the debt cycle.

- With training from a local CRP, he learned to prepare Jiwamrita and Bijamrita using his indigenous cow.
- The first season was challenging, with pressure to revert to chemicals due to visible pest attacks. However, with handholding, he persisted.

Impact & Findings:

- **Cost Reduction:** His cash investment in farming dropped to nearly zero. He no longer needed to take loans for inputs.
- **Improved Soil Health:** Within two seasons, the soil became softer and darker, and earthworm populations increased.
- **Food Security:** By intercropping legumes and vegetables with his paddy, his family's year-round food availability improved. The surplus, though small, was sold as "chemical-free" produce at a local haat (market) at a premium.

Key Takeaway: For small and marginal tribal farmers, Natural Farming is not just an agricultural practice but a tool for financial liberation and enhanced food sovereignty.

Case Study 3: The Horticulture Success in Himachal Pradesh

Background: Himachal Pradesh, with its significant apple and vegetable production, faces severe issues of soil degradation and high chemical residue in the fragile Himalayan ecosystem. The state's "PrakritikKheti Khushhal Kisan Yojana" aggressively promotes ZBNF.

Farmer Profile: Priya Sharma, an apple and vegetable grower in Shimla district.

Journey and Challenges:

- Priya's apple orchard was suffering from declining productivity and increased disease incidence.
- Transitioning a high-value horticulture

crop was considered risky. She started by converting one section of her orchard and her kitchen garden to Natural Farming.

- She used cow dung-based formulations and adopted mulching with wild grasses to retain soil moisture.

Impact & Findings:

- **Disease Reduction:** After an initial transition period, the apple trees showed improved resistance to fungal diseases.
- **Water Savings:** Mulching significantly reduced the need for irrigation, a critical benefit in the water-scarce hills.
- **Premium Market:** The vegetables from her kitchen garden were sold directly to tourists and local hotels as "organic and natural," fetching a price 20-30% higher than the market rate.

Natural Farming is viable and highly beneficial even for high-investment horticulture, offering solutions for soil health, water conservation, and access to premium markets.

Conclusion

An Integrated Path Forward

The National Mission on Natural Farming, as illustrated by these case studies, is demonstrating its potential to redefine Indian agriculture. From the large-scale, systemic change in Andhra Pradesh to the empowerment of individual tribal farmers in Odisha and the revival of horticulture in Himachal, the principles of ZBNF are showing adaptable and positive results.

The challenges of scaling up, ensuring market linkages, and scientific validation remain. However, the mission's focus on a decentralized, community-led structure, combined with the compelling evidence from the field, positions it as a cornerstone of India's journey towards an Atmanirbhar Bharat (Self-Reliant India) that is economically robust and ecologically secure.





Nano Urea and Their Chemical Behavior in Soil System

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Introduction

Global agriculture confronts the dual challenge of feeding an ever-expanding population while simultaneously mitigating the environmental consequences of intensive fertilizer use. Nitrogen (N), being the most limiting macronutrient for crop growth, is applied predominantly as urea [CO(NH₂)₂]-the most widely produced nitrogenous fertilizer in the world, accounting for over 50% of global N fertilizer consumption (FAO, 2023). However, conventional urea is characterized by notoriously low nitrogen use efficiency (NUE), typically 30–50%, owing to rapid hydrolysis, ammonia (NH₃) volatilization, nitrate (NO₃⁻) leaching, and gaseous losses via denitrification (Tilman et al., 2002; Ladha et al., 2020).

The advent of nanotechnology in agrochemistry has opened unprecedented avenues for redesigning fertilizer formulations at the nanoscale. Nano urea, developed by the Indian Farmers Fertiliser Cooperative Limited (IFFCO) in 2021, is a liquid nanofertilizer containing nitrogen nanoparticles (NNPs) dispersed in an aqueous colloidal suspension at a concentration of 4.0% w/v. Unlike conventional urea granules, nano urea particles are 10,000 times smaller in size (approximately 20–50 nm), resulting in an astronomically higher surface area-to-volume ratio, which fundamentally alters nitrogen release kinetics and soil-chemical interactions (IFFCO Nano Biotechnology Research Centre, 2021).

The soil, being a dynamic heterogeneous system, imposes intricate chemical, physical, and biological transformations on any substance introduced into it. Understanding the precise chemical behavior of nano urea—from dissolution and hydrolysis to

nitrification, adsorption, chelation and gaseous emissions—is therefore of paramount scientific importance. This article synthesizes current knowledge on the physicochemical properties of nano urea, its mechanistic fate in soil, and the agronomic and environmental implications for sustainable crop production.

Synthesis and Physicochemical Properties of Nano Urea

1. Synthesis Approaches

Nano urea is synthesized using top-down and bottom-up nanotechnological approaches. The most commercially viable method involves the chemical precipitation and polymerization of urea molecules within colloidal polymer matrices (e.g., polyvinyl alcohol, chitosan, or starch-based biopolymers), yielding a stable nano-dispersion. IFFCO employs a proprietary nano biotechnology process using a high-energy ball milling and ultrasonication protocol combined with polymer encapsulation to achieve



uniform particle size distribution in the range of 20–50 nm (Singh et al., 2021).

Alternative synthesis routes include:

- **Emulsion polymerization:** Formation of nano-capsules enclosing urea core within a cross-linked polymer shell.
- **Layer-by-layer assembly:** Electrostatic deposition of polyelectrolyte multilayers on urea nanocrystals for controlled coating thickness.
- **Sol-gel method:** Incorporation of urea

into silica-based nanomatrix through tetraethyl orthosilicate (TEOS) hydrolysis, yielding mesoporous nanocarriers.

- **Green synthesis:** Bio-fabrication using plant extracts (aloe vera, neem, moringa) acting as stabilizing and capping agents to reduce nanoparticle aggregation.

2 Physicochemical Characteristics

The physicochemical properties of nano urea that govern its behavior in soil are distinctly different from conventional urea (Table 1).

Table 1. Comparative physicochemical properties of conventional urea and nano urea

Property	Conventional Urea	Nano Urea
Particle size	1–4 mm (prilled/granular)	20–50 nm
N content	46% (solid)	4% w/v (liquid)
Surface area	Low (cm ² /g)	Extremely high (m ² /g)
Solubility in water	Highly soluble (~1080 g/L)	Colloidal dispersion
Release pattern	Rapid/uncontrolled	Slow, controlled
Zeta potential	N/A	-25 to -40 mV (stable)
pH of solution	~7.0–7.5	~6.8–7.2
Volatilization loss	High (15–40%)	Very low (<5%)
Leaching potential	High	Low to moderate

The negative zeta potential (-25 to -40 mV) of nano urea nanoparticles confers colloidal stability, preventing aggregation in aqueous suspension. This electrostatic repulsion between particles is critical for uniform foliar or soil application. The high surface area facilitates enhanced interaction with soil colloids, root surfaces, and biological enzymes, resulting in superior nutrient delivery efficiency compared to bulk urea.

Chemical Behavior of Nano Urea in Soil

1. Hydrolysis Kinetics

The fundamental step in nitrogen release from urea (both conventional and nano) in soil is enzymatic hydrolysis catalyzed by urease (EC 3.5.1.5), a nickel-metalloenzyme ubiquitous in soil microbial communities and plant residues. The reaction proceeds as:

$$\text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O} \rightarrow 2\text{NH}_3 + \text{CO}_2 \quad [\text{Urease}]$$

$$\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$$

In conventional urea, this hydrolysis occurs within 24–72 hours of soil application, leading to a rapid surge in NH_3^+ and NH_3 concentrations, pH elevation, and concomitant NH_3 volatilization. In nano urea, the polymer coating and nanoparticle architecture act as a physical and chemical barrier to urease access, dramatically slowing the hydrolysis rate. Studies have demonstrated that the hydrolysis half-life ($t_{1/2}$) of nano urea can be 3–5 times longer than conventional urea under equivalent temperature and moisture conditions (Kottegoda et al., 2017; DeRosa et al., 2010).

The retarded hydrolysis in nano urea systems can be attributed to: (i) steric hindrance imposed by polymer shells limiting urease–substrate contact, (ii) electrostatic repulsion between negatively charged nanoparticle surfaces and anionic urease active sites, and (iii) diffusion-controlled



nitrogen release from the nano-particle core through the polymer matrix.

2. Adsorption–Desorption Dynamics

Nitrogen from nano urea interacts with soil colloids-clay minerals (montmorillonite, kaolinite, illite), metal oxides (Fe_2O_3 , Al_2O_3), and soil organic matter (humic and fulvic acids)-through diverse adsorption mechanisms. The key interactions include:

- **Electrostatic adsorption:** NH_4^+ ions generated from nano urea hydrolysis are adsorbed onto negatively charged clay mineral surfaces through cation exchange mechanisms. The high cation exchange capacity (CEC) of 2:1 layer silicates (e.g., smectite, montmorillonite) facilitates NH_4^+ retention, reducing leaching risk.

- **Specific adsorption:** Urea molecules and amide-N can form hydrogen bonds with hydroxyl groups on iron and aluminum oxide surfaces, enabling inner-sphere surface complexation.

- **Ligand exchange:** Ammonium ions may participate in ligand exchange reactions at the surfaces of aluminum oxide, displacing OH^- groups.

- **Interlayer fixation:** NH_4^+ , due to its similar ionic radius to K^+ , can become trapped (fixed) within the interlayer spaces of 2:1 clay minerals, rendering it temporarily unavailable but protecting it from leaching.

Nano urea's smaller particle size and higher surface charge density enhance initial contact with soil colloid surfaces. Adsorption isotherms of nano urea-derived NH_4^+ tend to follow the Langmuir model in soils with higher clay content, while Freundlich isotherms better describe adsorption in sandy or organic-rich soils (Nair et al., 2010). The desorption of adsorbed NH_4^+ is governed by soil pH, ionic strength, competing cations (Ca^{2+} , Mg^{2+} , K^+), and soil water content.

3. Nitrification Pathway

Following hydrolysis and NH_4^+ release,

nitrification-the biological oxidation of ammonium to nitrate-proceeds in two sequential steps mediated by autotrophic nitrifying bacteria:

Step 1 (Ammonia Oxidation): $\text{NH}_4^+ + 1.5\text{O}_2 \rightarrow \text{NO}_2^- + \text{H}_2\text{O} + 2\text{H}^+$

(*Nitrosomonas*, *Nitrosospira* spp.)

Step 2 (Nitrite Oxidation): $\text{NO}_2^- + 0.5\text{O}_2 \rightarrow \text{NO}_3^-$

(*Nitrobacter*, *Nitrospira* spp.)

The controlled and gradual release of NH_4^+ from nano urea prevents the substrate surge that typically overwhelms nitrifying microbial communities in conventional urea-amended soils. This temporal synchrony between N release and plant N demand not only enhances NUE but also reduces NO_3^- accumulation in soil-a key driver of NO_3^- leaching and N_2O emissions through denitrification. Several incubation studies have documented 20–40% reduction in peak nitrification rates in nano urea treatments compared to conventional urea (Singh et al., 2021; Trenkel, 2010).

Furthermore, nano urea polymer coatings, particularly those incorporating nitrification inhibitors (e.g., 3,4-dimethylpyrazole phosphate [DMPP] or dicyandiamide [DCD]) in advanced formulations, can further suppress ammonia monooxygenase (AMO) enzyme activity-the rate-limiting enzyme in nitrification-thereby extending the window of NH_3 availability in the root zone.

4. Denitrification and Gaseous N Losses

Denitrification-the microbially mediated anaerobic reduction of NO_3^- to gaseous nitrogen species (N_2O , NO , N_2)-represents a significant pathway of N loss in flooded and poorly drained soils. The denitrification sequence is:

$\text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$

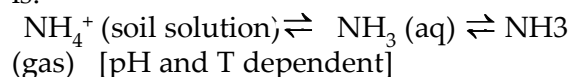
Because nano urea releases NH_4^+ gradually, the rate of NO_3^- production via nitrification is buffered, thereby constraining the substrate availability for denitrifying



bacteria (*Pseudomonas*, *Bacillus*, *Paracoccus spp.*). Life cycle assessment (LCA) studies and gas flux measurements report 20–35% lower cumulative N₂O emissions from nano urea-amended paddy soils compared to conventional urea treatments (Bolan et al., 2022). This has profound implications for climate change mitigation, given that N₂O has a global warming potential (GWP) approximately 273 times greater than CO₂ over a 100-year horizon (IPCC, 2021).

5. Ammonia Volatilization

Ammonia volatilization from soil following urea application is a major nitrogen loss pathway in alkaline and calcareous soils, especially under high temperature and low soil moisture conditions. The thermodynamic relationship governing volatilization is:



Nano urea fundamentally suppresses volatilization through: (i) delayed hydrolysis reducing instantaneous NH₃ generation, (ii) the polymer matrix acting as a physical vapor barrier, and (iii) maintenance of a more uniform and lower soil pH in the vicinity of fertilizer particles compared to the alkaline micro-zones created around dissolving conventional urea granules. Field studies in semi-arid environments have reported NH₃ volatilization losses of merely 2–8% from nano urea vs. 18–35% from prilled urea under comparable conditions (Chauhan et al., 2022; Shaviv, 2001).

6. Interaction with Soil Organic Matter and Microbial Biomass

Soil organic matter (SOM): composed of humic acids (HA), fulvic acids (FA), and humin fractions-plays a critical role in nano urea transformation. Humic acids, with abundant carboxyl (–COOH) and phenolic (–OH) functional groups, can complex with metal ion contaminants associated with nanoparticle stabilizers and form organo-

mineral associations that modulate N availability. The high surface energy of nano urea particles facilitates stronger sorption onto humic substance surfaces compared to conventional urea molecules, reducing N mobility.

The soil microbial biomass nitrogen (MBN) pool also responds distinctly to nano urea additions. Several studies employing phospholipid fatty acid (PLFA) profiling and 16S rRNA metagenomic analyses indicate that nano urea application promotes a more stable and diverse soil microbial community, attributed to the absence of substrate shock (sudden NH₄⁺ surge), thereby enhancing soil biological fertility over cropping cycles (Giraldo et al., 2014; Raliya et al., 2016).

7. Nanoscale Surface Reactions and Chelation Chemistry

At the nanoscale, the extraordinarily high surface energy and quantum confinement effects of nitrogen nanoparticles modify chemical reactivity patterns in ways not observed in conventional fertilizer systems. Key nanoscale phenomena include:

- **Surface chelation:** Nitrogen atoms on nanoparticle surfaces can form coordination complexes with soil micronutrients (Fe^{2+/3+}, Mn²⁺, Zn²⁺), facilitating their mobilization and co-transport to plant roots - a synergistic effect absent in conventional urea.

- **Catalytic activity:** Nano urea particles may exhibit surface-catalytic properties, accelerating or modifying enzyme-substrate interactions in soil biochemical reactions.

- **Nanoparticle dissolution kinetics:** Unlike bulk solids governed by Nernst dissolution theory, nanoparticle dissolution follows the Ostwald–Freundlich equation, where solubility increases exponentially with decreasing particle radius, enabling dynamic, demand-responsive nutrient release.



- **Nano-bio interactions:** Nanoparticles interact with root exudates (organic acids, mucilage, phytosiderophores) altering the rhizosphere chemistry and N availability in the narrow zone of intense biological activity.

Nitrogen Use Efficiency and Crop Performance

Nitrogen use efficiency (NUE) is defined as the ratio of N accumulated in the crop biomass to the total N applied via fertilizer. The multi-dimensional aspects of NUE encompass agronomic NUE (ANUE), physiological NUE (PNUE), and recovery efficiency (RE). Nano urea consistently enhances all dimensions of NUE owing to its controlled release kinetics.

Meta-analyses of over 50 field trials across diverse crop species (wheat, rice, maize, soybean, cotton) and soil types conducted by IFFCO's Nano Biotechnology Research Centre report:

- Average NUE improvement of 25–40% over conventional urea (IFFCO, 2021).
- Equivalent or superior grain yields achieved with 50% reduction in nitrogen dose when nano urea is used as a foliar supplement.
- Significant improvement in crop quality parameters: protein content, starch accumulation, thousand-grain weight.
- Enhanced root biomass and root architecture due to sustained N supply during critical vegetative growth stages.

Studies by Usha Rani et al. (2022) on wheat (*Triticum aestivum* L.) in Haryana demonstrated that foliar application of nano urea at tillering and flag leaf stages produced a 6.2% increase in grain yield with 50% lower N application, corroborating the superior delivery efficiency of nano urea nanoparticles. Similar results were reported for transplanted rice (*Oryza sativa* L.) in Punjab soils, where nano urea supplementation increased N uptake by 23% relative

to sole urea application (Kalia et al., 2023).

Environmental Implications and Sustainability

The environmental consequences of conventional nitrogen fertilizer overuse are well-documented and include groundwater NO_3^- contamination, eutrophication of aquatic ecosystems, soil acidification, disruption of biogeochemical nitrogen cycling, and contribution to the greenhouse effect via N_2O emissions. Nano urea offers compelling advantages in each of these domains.

1 Reduction in Nitrate Leaching

The delayed nitrification associated with nano urea limits the conversion of NH_4^+ to the mobile, anionic NO_3^- form, thereby mitigating leaching losses into subsoil and groundwater. Lysimeter experiments in sandy loam soils demonstrated 35–50% lower cumulative NO_3^- leaching in nano urea treatments relative to prilled urea, particularly during heavy rainfall events in the post-application period (Trenkel, 2010; Liu et al., 2022).

2 Mitigation of Climate Forcing

As discussed in Section 3.4, the temporal buffering of nitrification and consequent denitrification by nano urea markedly reduces N_2O fluxes from agricultural soils. Additionally, reduced NH_3 volatilization lowers the dry and wet deposition of reactive nitrogen to adjacent terrestrial and aquatic ecosystems—a phenomenon known as nitrogen deposition which contributes to biodiversity loss and soil eutrophication (Fowler et al., 2013).

3 Nano-Ecotoxicology Concerns

Despite its promise, nano urea raises legitimate ecotoxicological concerns that merit rigorous scientific investigation. The long-term fate of polymer nanocarriers in soil—their biodegradability, potential accumulation, interaction with soil fauna (earthworms, nematodes, microarthropods), and



capacity to adsorb and transport organic pollutants and heavy metals-remains inadequately characterized. Studies using the earthworm model (*Eisenia fetida*) indicate biocompatibility of chitosan-based nano urea at recommended doses but cytotoxic effects at supraoptimal concentrations ($>200 \text{ mg N kg}^{-1}$ soil) (Fraceto et al., 2016). Further long-term soil mesocosm and field ecotoxicological studies are warranted.

Regulatory Framework and Commercial Landscape

IFFCO's nano urea (liquid) received approval from the Fertilizer Control Order (FCO) of India in May 2021, marking a landmark regulatory recognition of nanotechnology-based fertilizers in a major agricultural economy. The product specification mandates a minimum nitrogen content of 4.0% w/v, particle size $\leq 100 \text{ nm}$, and compliance with toxicity and stability standards. A 500 mL bottle of nano urea is reported to be equivalent in agronomic effect to one 45 kg bag of urea in foliar application scenarios, representing a dramatic reduction in logistics, packaging, and carbon footprint.

Globally, the nano-fertilizer market is projected to expand at a compound annual growth rate (CAGR) of 14.2% from 2023 to 2030, driven by policy mandates on NUE improvement, precision agriculture adoption, and environmental regulations on nitrogen losses (Grand View Research, 2023). Several nations including China, Brazil, the USA, and the EU are at various stages of regulatory framework development for nano-agrochemicals.

Future Research Directions

Despite significant advances, the science of nano urea is still in a formative stage. Priority research areas include:

- **Long-term soil health and microbiome studies:** Assessing the chronic effects of nano urea on soil enzyme activities (urease,

dehydrogenase, phosphatase), microbial diversity indices, and functional gene expression (nitrification, denitrification genes) across multiple cropping cycles using omics approaches.

- **Soil-type specificity:** Systematic evaluation of nano urea performance across soil taxonomic orders (Entisols, Inceptisols, Vertisols, Alfisols, Oxisols) to elucidate soil texture, mineralogy, and pH effects on release kinetics.

- **Nano-N fate tracing:** Employment of ^{15}N isotope labeling combined with NanoSIMS (nano-scale secondary ion mass spectrometry) to precisely track N release from individual nanoparticles in situ in soil and plant tissues.

- **Smart nano fertilizers:** Development of stimuli-responsive nano urea systems that release N in response to specific soil triggers -temperature, pH, moisture, or enzymatic activity-for hyper-precision nutrient synchrony.

- **Life cycle assessment (LCA):** Comprehensive cradle-to-grave environmental LCA of nano urea production, application, and soil transformation compared to conventional N fertilizer supply chains.

- **Regulatory harmonization:** Development of internationally harmonized testing protocols and safety thresholds for nano-agrochemical registration and risk assessment.

Conclusion

Nano urea represents a scientifically sound and agronomically promising innovation in nitrogen fertilizer technology. Its distinctive physicochemical architecture-ultra-small particle size, high surface area, controlled negative zeta potential, and polymer encapsulation-fundamentally modulates the nitrogen transformation pathways in soil. The retarded hydrolysis, reduced nitrification rate, dampened denitrification substrate flux, and minimized ammonia



volatilization collectively translate into higher nitrogen use efficiency, lower environmental nitrogen losses, and comparable or superior crop yields at reduced nitrogen application rates.

However, the transition from proof-of-concept to broad-scale adoption necessitates a deeper mechanistic understanding of nano-soil interactions, long-term ecological risk assessments, and the development of robust regulatory frameworks. The integration of nano urea technology within precision and climate-smart agricultural systems holds significant promise for addressing the twin imperatives of food security and environmental sustainability in the 21st century. Advancing the fundamental and applied science of nano urea will be pivotal in shaping the next generation of nitrogen management paradigms.

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