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Artificial Lighting: Boon for Floriculture

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Introduction

Light is a vital environmental factor that affects plant growth and development by acting on plants not only as the sole energy source of photosynthesis, but also as the kind of external signal. Application of artificial light (AL) is becoming popularized, because it is used for improving yield, extending the production season and off season production by photoperiodic management. Successful artificial lighting for plant growth balances the quality, intensity and duration. A number of different artificial light sources are commercially available such as incandescent lamps, fluorescent lamps, high pressure sodium lamps and more recently light emitting diodes (LED) that differ in the light quality they emit (Gupta and Agarwal., 2017).

Basic requirement of plants are light, carbon dioxide, water, soil and nutrients. Among these five elements light plays an important role because; it is essential for photosynthesis which is fundamental metabolic process in the plants, for producing the food. Spectrum of light having different wavelength of energy produced by light source. Photosynthetically active radiation (PAR) present between 400-700 nm. The wavelength mainly depends on colour of light. Solar light is basic and cheaply available source of light in the environment, but we can't get same amount of light throughout the year it is mainly depend on weather. By using artificial light (AL) we can give light throughout the year and manipulate the spectrum of light. Light is a form of electromagnetic radiation and sole energy source of photosynthesis.

Artificial light means sources can consist of a filament that uses electricity or halogen gas to glow or an electronic device that emits light. Light is a form of electromagnetic radiation that is visible to the human eye. Light is one of the most important environmental factors that regulate plant growth and development. Plants need light not only for photosynthesis but also for fine-tuned regulation of their development. UV, blue and red radiations are involved in diverse photomorphogenic responses such as seedling development, vegetative growth and flowering. A large amount of available literature is on the perception and the plant response to red (R), far-red (FR) and R/ FR ratio, mediated by phytochromes. Application of artificial light (AL) in ornamental plants is becoming popular. It is used for improving yield, extending the production season, improving product quality and as photoperiodic light for the control of flowering in day length-sensitive species. A successful artificial lighting for plant growth must balance quality, intensity and photoperiod (Egea *et al.*, 2014). Light quality refers to the spectral composition of the light source.

Need

- **Used for improving yield:** Artificial lighting helps flowering plants by regulating light duration and intensity, improving photosynthesis and creating optimal growing conditions.

- **Extends the production season:** Artificial lighting provides the ability to control and extend the growing season for flowering plants by supplementing natural light, regulating photoperiod, and creating optimal light conditions for year-round production.
- **Improves the product quality:** Artificial lighting enhances the quality of flowering plants by improving various factors such as flower size, color, symmetry, post-harvest longevity, and overall plant health. By controlling light intensity, spectrum, and duration, growers can optimize the growing conditions for plants, resulting in consistent, high-quality flowers.
- **Off season production:** Careful photoperiod management allows growers to produce flowers during off-seasons by controlling the light and dark cycles that trigger flowering. Whether it's extending the day for long-day plants or providing longer nights for short-day plants, artificial light enables growers to achieve year-round flowering, higher yield and better-quality flowers, even in winter or in regions with limited sunlight.

Types of artificial lighting

- **Replacement lighting:** Complete replacement of solar radiation for indoor growth rooms and growth chambers
- **Supplemental lighting (SL):** It is used in greenhouses to supplement periods of low natural light. One of the most costeffective uses of SL is during the production of young plants, when plants are grown at a high density
- **Photoperiod lighting:** Used to stimulate or influence photoperiod dependant plant responses such as flowering or vegetative growth.

Classification of plants depending upon the duration of photoperiod

1. Short day plants (SDP): It needs long dark periods and short light periods for flowering.

Eg: Cosmos, Poinsettia, chrysanthemum, Salvia

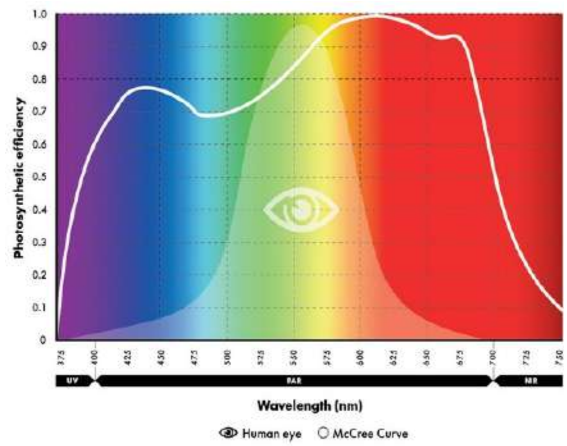

Fig. 1: Photosynthetic efficiency of the plant

2. Long day plants (LDP): It needs long light periods and short dark periods for flowering.

Eg: Delphinidium, Stock, Calendula, Carnation, Sweet williums

3. Day neutral plants (DNP): Not affected by day length. Eg: Balsam, French marigold

For photosynthesis, plants respond strongest to blue and red light, and to red and infra-red light wavelengths for photoperiod growth responses and germination control. The intensity, duration, direction and spectral quality of light radiation that plants receive has an effect on photosynthesis, flowering, climate response (temperature and water loss) and plant shape (photomorphogenesis).

The phytochromes exist in red (R; 600-700 nm) and far-red (FR; 700-800 nm) absorbing forms (PR and PFR, respectively). The ratio of R to FR light influences the phytochrome photoequilibria (PFR/PR+FR), which influences flowering in photoperiodic crops and stem extension in shade avoiding plants (Fig.

1). A low PFR/ PR+FR promotes stem extension and flowering in long day plants (LDPs). Thus, many long day plants (LDPs) flower most rapidly when artificial lighting contains FR light, particularly at the end of the photoperiod (Downs and Thomas, 1982). When long day plants (LDPs) are grown under light deficient in FR, flower initiation, development, or both can be delayed as observed in snapdragon, bellflower, coreopsis, petunia, pansy and black henbane. When the natural day length is short, flowering of long day plants (LDPs) can be promoted by providing artificial lighting at the end of the day (day extension) or during the middle of the night (night interruption, NI) to create long days (LD). NI lighting is generally more effective for inducing flowering in long day plants (LDPs) than day extension, even if the intensity and duration of the supplemental lighting are equal (Gupta and agarwal, 2017).

Artificial lighting systems

1. Incandescent lamps (IL): Incandescent lamps (IL) produce light by heating substances to a temperature at which they glow and are luminous. They are the cheapest option and their use in horticultural lighting has been limited due to their low electrical efficiency, low light emission, unbalanced spectrum (reduced emission in the blue region) and short life time. Incandescent bulbs convert only 6% of the electricity to PAR (photo-synthetically active radiation) light.

2. Fluorescence lamps (FL): They are low pressure mercury electric discharge lamp consists of a glass tube filled with a mixture of argon gas and mercury vapour at low pressure. They have intermediate luminous efficiency between incandescent lamps (IL) and high-intensity discharge lamps, and a lifespan similar to that of metal halide lamps (MHL). Fluorescence lamps are available in a range of spectral qualities. Cool white lamps, which are relatively inexpensive, and full-spectrum lamps are available options for supplementary and replacement lighting applications, respectively.

3. Metal halide lamps (MHL): Metal halide lamps use mercury vapour in a quartz arc tube and mixtures of sodium and thorium. The electrical arc vaporizes the halides, heating them to a plasma state, whereupon they emit line spectra characteristic of the elements in the plasma. Metal halide lamps produce a relatively full spectrum of white light that is often preferable to the yellowish light of high pressure sodium. The emission spectra are highly concentrated in the yellow-orange-red range (500-650 nm). They can convert 30% of the electricity to PAR light. They are widely used in greenhouse production due to their high PAR emission, electrical efficiency, long life and relatively moderate cost of installation. HPS lamps spectrum is poor in blue light.

4. Light-emitting diodes (LED): LED is made up of a material called a semiconductor. This material is solid in nature, which makes LEDs a little more durable. When electricity is passed through the semiconductor material, the electrons inside begin whizzing, which releases energy in the form of visible light. LED lamps have great potential due to their long lifespan, low radiant heat output, their ability to emit in a controlled spectral composition (e.g., red and blue wavelengths) and the adjustment of light intensity. 40% of the energy is converted to light for red LED and 38% for blue LED. The use of Light Emitting Diode (LED) technology for horticultural lighting is becoming increasingly feasible from an economic point of view. Plant growth and development was strongly affected by the different treatments. White light and blue light were found to be the most efficient for plant growth. However, stem elongation was dramatically enhanced by blue light in certain circumstances.

Fig. 2: LED light

Fig. 3: Flower regulation of chrysanthemum under green house

Application of artificial lighting systems in floriculture

- **Pot plant production:** In poinsettia cvs. Christmas Spirit and Christmas Eve recorded lowest shoot length (95 mm and 104 mm, respectively) and internodal length (5.9 mm and 5.6 mm, respectively) further, it was reported that, in cv. Christmas Eve endogenous production of indole 3 acetic acid (695 ± 5.5 ng g-1), gibberellins (1099.9 ± 38.6 ng g-1) and cytokinin (75.0 ± 6.1 ng g-1) were low in of end-of-day red light compared to end-of-day far-red light (Islam *et al*., 2014).
- **Bedding plants:** In carnation var. Dreambyul recorded 100 per cent rooting after 10 days and 25 days of light supplemented with metal halide lamp and also recorded highest root length (1.6 cm and 9.1 cm, respectively), number of roots (16 and 36 respectively), root fresh weight (19.6 mg and 267.8 mg, respectively) and dry weight (2.2 mg and 28.7 mg, respect-ively) (Wang *et al*., 2020).
- **Indoor landscaping:** In indoor living wall planted with two plant species viz., *Spathiphyllum wallisii* and *Soleirolia soleirolii* fixed 1 m away from fluorescent lamp (FL) was recorded highest total fresh weight (121 g and 29.9g, respectively), total dry weight (12.4 g and 6.1 g, respectively) and leaf area (1339 cm2 and 966.9 cm2, respectively) (Egea *et al*., 2019).
- **Flower regulation:** Thakur and Grewal (2019) studied on growth regulation and off-season flowering through night breaks in *chrysanthemum morifolium* (RAMAT) cv. Anmol. The results revealed that, the plant height (64.49 cm), number of branc-hes per plant (3.2) and number of leaves per plant (77.44) had positively affected with increa-sed duration of night interruption (120 min) after 45 days of night interruption (NI). Further, the flowering was significantly delayed (156.40 days) and number of flowers per plant increased (80.25) as the duration of night interruption was increased (120 min)
- **Tissue culture:** The implementation of LEDs as an illumination source for in vitro gerbera culture revealed that the most suitable light composition is 70%/30% red and blue for shoot multiplication. Plants grown under red light supplemented with blue display enhanced vegetative growth and micropropagation rates. Regarding rhizogenesis, red light is considered to be best (Llewellyn *et al*., 2019).

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Sustainable Dragon Fruit Cultivation: A Way Towards Eco-Friendly Farming

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Introduction

Fruit cultivation sustainability has emerged as a valuable aspect in the 21st century with mounting concerns regarding environment pollution, water shortages and the demand for healthy food. Dragon fruit (*Hylocereus* sp.) or pitaya holds great promise as a sustainable agriculture crop because it is low on inputs and a versatile crop. It is a subtropical and tropical fruit that is appreciated for its beauty, flavor and nutritional value. A 100 g serving yields water (87 g), carbohydrates (11.0 g), fiber (3.0 g) and basic vitamins and minerals (Thokchom *et al*., 2019). A native to Central and South America, today it is also grown in Asia, the Middle East and in certain states of India such as Maharashtra, Gujarat and Karnataka (Mizrahi & Nerd, 1999; Nobel & De la Barrera, 2002). Dragon fruit is tolerant to hot and dry weather and may be produced organically (Trivellini *et al*., 2020). In this article, the author investigates sustainable farming methods, eco-benefits and the socio-economic prospects of growing dragon fruits. Thus, sustainable cultivation of dragon fruit will encompass eco-friendly agricultural practices, optimal use of natural resources and its capacity to improve farmers' income and food security.

Environmental Issues

Though dragon fruit (*Hylocereus* sp.) is famous for its low water requirement and flexibility, its increasing cultivation in India has raised environmental issues. The application of RCC poles and drip systems can cause soil compaction, while monoculture diminishes biodiversity and enhances pest threats. Irrigation is required at regular intervals during flowering, which can put a strain on water resources in dry regions. Inefficient irrigation also poses the risk of salinization and waterlogging (Mansingh & Padhan, 2023).

Economic and Social Aspects

Dragon fruit (*Hylocereus* sp.) production offers great economic and social advantages, particularly in India's arid and semi-arid areas. Seeing its potential, the Indian government, under the Mission for Integrated Development of Horticulture (MIDH), plans to increase cultivation to 50,000 hectares, with Gujarat and Haryana providing subsidies of up to ₹ 4.5 lakh per hectare (The Hindu, 2022).

Socially, dragon fruit is promoting rural livelihood and food security, particularly for poor farmers utilizing degraded or rainfed agricultural lands (Agro Spectrum India, 2023). In Southeast Asia, smallholder dominance of production assures assured incomes and rural progress. Land ownership and communication among farmers are among the key social factors and technological factors include innovation adoption and fruit quality. Institutional factors, such as agricultural extension and access to finance are essential (Ningsih *et al*., 2022).

Site Selection and Soil Management

Good site selection and soil management are critical for successful dragon fruit (*Hylocereuss* sp.) production. Dragon fruit prefers tropical and subtropical climates with a temperature of 20°C to 35°C and high light and good air movement. It is ideally adapted for arid and semi-arid environments with well-draining soils to avoid root rot (Mansingh & Padhan, 2023).

The plant is fond of slightly acidic to neutral pH (5.5 to 7.0) and thrives in sandy loam or organic matter-rich loamy soils. Waterlogging must be avoided, as it negatively impacts root growth. Sloped lands or raised beds or ridges are suggested to promote drainage. Pre-plantation

Soil testing allows nutrient determination and provides guidance on the use of organic or inorganic manures. Adding organic compost, green manure and vermicompost improves soil structure and fertility. Sustainable practice starts with choosing land that does not need deforestation or drastic changes to natural habitats. Using underutilized or degraded agricultural land is an environmentally friendly option.

Soil Conservation Techniques

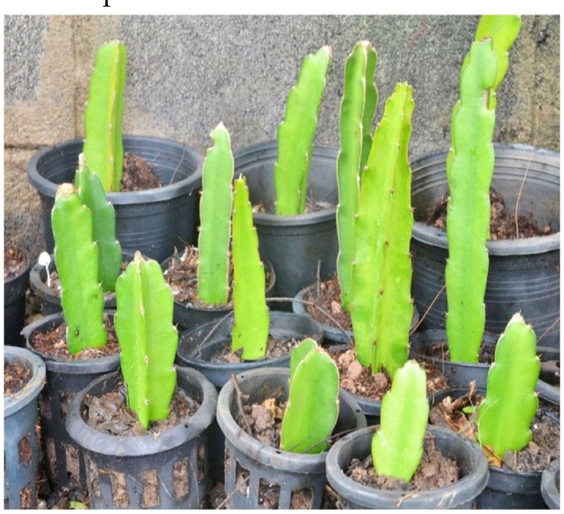
Efficient soil conservation is crucial to sustainable dragon fruit (*Hylocereus* sp.) production, particularly in arid areas. Methods such as reduced tillage, cover crops and organic mulching conserve soil structure, increase organic matter and decrease erosion. These practices conserve soil organic carbon (SOC), an important fertility and productivity indicator. Intensive tillage and monoculture lower SOC, while conservation tillage and crop rotation enhance it, increasing soil porosity and nutrient retention (Gómez *et al*., 2022) routine testing of the soil promotes effective utilization of nutrients and reduces chemical applications, thus aiding long-term sustainability and resistance to dragon fruit cropping.

Sustainable dragon fruit cultivation

Sustainable Propagation and Planting Practices

Healthy, disease-free and locally adapted stem cuttings should be used for sustainable dragon fruit (*Hylocereus* sp.) cultivation.

Stem cuttings of 20-25 cm in length are usually used. These should be made one to two days in advance of planting, with the latex allowed to dry naturally to avoid infections. Pre-treatment of the cuttings with fungicides prior to planting further minimizes disease susceptibility (Jana & Moha, 2024). Anchorage and nutrient supply are provided by growing media. Media containing biofertilizers like nitrogen-fixing and phosphorus-solubilizing bacteria improve nutrient availability and promote plant growth through the production of growth-promoting substances. This encourages a healthy soil micro flora and maintains long-term soil fertility. Tissue culture propagation also ensures uniform, healthy, and disease-free planting material. Support structures, like trellises from locally sourced bamboo or recycled concrete poles, reduce the carbon footprint. Correct plant spacing ensures good air circulation and penetration of light, which improves productivity and decreases disease pressure.



Sustainable Propagation & Planting Practices

Water management

Effective management of water plays a significant role in successful cropping of dragon fruit (*Hylocereus* sp.), especially in arid and semi-arid conditions. Although the crop is drought-resistent, the crop requires routine irrigation during periods of flowering and fruiting. Drip irrigation is used since it applies water in an efficient manner and minimizes disease hazards (Mansingh & Padhan, 2023). Root rot and soil salinity can result from over-irrigation, so it is necessary to check soil moisture. Organic mulching retains moisture and prevents evaporation. Rainwater harvesting systems also enhance water supply and facilitate production throughout the year, favouring sustainable and resource-conserving farming practices.

Organic and Integrated Nutrient Management

Decreasing dependency on synthetic fertilizers is vital for sustainable production of dragon fruit (*Hylocereuss* sp.). Overuse of chemicals causes nutrient runoff and soil degradation. Organic amendments such as compost, vermicompost and green manures enhance soil fertility and plant performance. Using 12 kg of compost per pillar per year dramatically increased fruit yield in red pitaya (Hoe, 2014). Likewise, vermicompost 100% nitrogen and phosphate-solubilizing bacteria (PSB) and vesicular-arbuscular mycorrhizae (VAM) 10 kg/ha increased flowering and yield (Siddiqua 7, 2024).

Integrated Nutrient Management (INM) integrates organic, biological and low levels of mineral fertilizers to deliver balanced nutrition. The combination of farmyard manure with minor quantities of synthetic nutrients maintains soil health. Biofertilizers such as Azospirillum, Azotobacter and PSB increase nutrient uptake, nitrate reductase activity and microbial diversity. VAM colonization to 80% enhances phosphorus availability, whereas PSB and Azospirillum treatments enhance soil nitrogen and nutrient absorption by plants considerably, increasing the overall productivity.

Integrated Pest Management (IPM) and Disease Prevention

Integrated Pest Management (IPM) in dragon fruit production integrates biological, cultural and low chemical approaches to manage pests in a sustainable manner. It involves frequent field scouting, employing natural enemies such as lady beetles, crop rotation, sanitation and the use of botanical pesticides such as neem oil to minimize chemical application. IPM protects pollinators and beneficial insects.

For disease control, particularly against stem rot and anthracnose, proper pruning, sanitation of tools and plant spacing are critical. Remove infected stems. Apply fungicides such as thiophanate-methyl or biofungicides, if necessary, to suppress infections without affecting the environment.

Resilience and Adaptation

Dragon fruit is drought- and heat-resistant by nature, performing well in dry tropical or subtropical conditions. Mulching, windbreaks and agroforestry conserve water, mitigate temperature stress and enhance climate variability resilience. Intercropping with legumes or herbs enhances biodiversity, soil fertility, and economic stability.

Renewable Energy and Low-Carbon Practices

Solar-powered irrigation systems reduce emissions and costs of operation, with subsidies in most areas. Conservation tillage, cover crops and organic matter application increase soil organic carbon, enhancing fertility, water holding capacity, and supporting climate-friendly, low-carbon agriculture.

Certification and Market Access

- Organic and Fair-Trade Certification
- Direct Marketing and Value Addition

Education and Capacity Building for sustainable dragon fruit cultivation

- Farmer Training Programs
- Community-Based Approaches

Government Incentives and Research Innovation

In order to encourage sustainable dragon fruit production, governments need to provide subsidies, access to credit and technical assistance for organic agriculture, solar power, and water-saving technologies. Initiatives such as the Mission for Integrated Development of Horticulture (MIDH) encourage productivity, quality assurance and market facilitation. Land-use policies need to discourage forest clearance and encourage ecological rehabilitation. Research investment is necessary to create disease-resistant varieties, enhance cultivation methods and discover value-added applications such as functional foods and natural pigments. Public-private university collaborations expedite innovation, rendering dragon fruit farming more productive, sustainable and financially attractive

Conclusion

This essay is intended to present the sustainable cultivation of dragon fruit. Organic cultivation has a crucial role in dragon fruit production and also has a large impact on agro ecosystem. Sustainable dragon fruit cultivation provides a hopeful way toward ecologically sound and economically sustainable agriculture. It is suggested that vegetative mode of propagation by stem cuttings in dragon fruit using bio-fertilizers can be a dependable one for commercial production of planting materials and it is rapid method too. By applying ecological principles, effective use of resources and social justice, farmers can satisfy the needs of the present without reducing the ability of future generations to produce food. As the global market for dragon fruit keeps rising, adopting green ways will not just save the Earth but will also empower our farmer communities. Combining heritage expertise, technology, and favouring policies can drive dragon fruit agriculture to be compatible with the planet.

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Allelopathic Interactions: A Green Solution for Managing Agricultural Pests and Pathogens

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Introduction

Agriculture faces constant threats from pests and diseases, impacting crop yield and quality. While chemical pesticides and fertilizers have traditionally been used, concerns over environmental impact, resistance development and human health risks have led to the search for sustainable alternatives. One promising approach is allelopathy, a natural phenomenon where plants release chemicals (allelochemicals) that influence the growth and behaviour of surrounding organisms. This eco-friendly strategy offers potential solutions for pest and disease management while reducing reliance on synthetic chemicals.

Allelopathy in Disease Management

Plants produce allelochemicals with antimicrobial, antifungal and anti-phytopathogenic properties, helping to suppress various crop diseases

- **Fungal Suppression:** Mustard (*Brassica juncea*) releases glucosinolates toxic to soil fungi like *Fusarium* and *Rhizoctonia* (Ibrahim *et al*., 2022). Garlic (*Allium sativum*) and onions (*Allium cepa*) release sulphur compounds with antifungal effects (Singh & Sharma, 2021).
- **Bacterial Control:** Plants such as oak (*Quercus* spp.) release tannins that inhibit bacterial growth, reducing diseases like bacterial blight (*Xanthomonas* spp.) (Kumar *et al*., 2023).
- **Nematode Suppression:** Mustard and marigold (*Tagetes* spp.) produce compounds that deter plant-parasitic nematodes, reducing root damage and crop loss (Johnson *et al*., 2022).

Table-1: Allelopathic suppression of pathogens, nematodes.

Allelopathic source	Application mode/rate	Pathogen/disease suppression	Reference
Barley (*Hordeum vulgare* L.) + potato	Grown in rotation	55.1% reduction in inoculum intensity of *Rhizoctonia solani* (JG Kühn)	Larkin and Griffin, 2007
Turnip (*Brassica rapa* L.) + potato	Turnip (*Brassica rapa* L.) + potato	56.2% reduction in inoculum intensity of *Rhizoctonia solani* (JG Kühn)	

Allelopathic source	Application mode/rate	Pathogen/disease suppression	Reference
Indian mustard (*Brassica juncea* L.) + potato	Grown in rotation	45.5% reduction in inoculum intensity of *Rhizoctonia solani* (JG Kühn)	
Rice (*Oryza sativa* L.)	Root exudates (1.5 ml)	37% reduction in germination of *Fusarium oxysporum f.* sp. *Niveum* spores	Ren *et al.*, 2008
Neem (*Azadirachta indica* L.)	Leaf water extract (20% w/v)	53.22% reduction in the growth of *Fusarium solani f.* sp. *melongenae*	Joseph *et al.*, 2008
Neem (*Azadirachat indica* L.) cake	3% (w/w)	61.03% reduction in root-knot nematode (*Meloidogyne javanica)* females per root	Javed *et al.*, 2007

Allelopathy in Pest Management

Allelopathy also helps control insect pests and weeds:

- **Insect Repellence:** Plants like sorghum (*Sorghum bicolor*) and sunflower (*Helianthus annuus*) release chemicals that deter aphids and beetles. Mint (*Mentha* spp.) produces essential oils, such as menthol, which repel insects like ants and aphids (Wang *et al.*, 2023).
- **Weed Suppression:** Black walnut (*Juglans nigra*) releases juglone, which inhibits weed growth. Cereal rye (*Secale cereale*) and barley (*Hordeum vulgare*) suppresses weeds through chemical inhibition, reducing herbicide dependence (Patel & Rao, 2022).

Table- 2: Allelopathic suppression of insect-pests.

Allelopathic source	Application mode/rate	Insect suppression	Reference
Neem Azal-T/S	20 g a.i. ha-1	91.88% mortality of *Jacobiasca lybica* (Berg. and Zanon) nymphs	El Shafie and Basedow, 2003
California pepper tree (*Schinusmolle* Rev L.)	Ethanol extract (4.7% w/v)	91.77% mortality of elm leaf beetle (*Xanthogaleruca luteola* Müller)	Huerta *et al.*, 2010
Fig-leaf goosefoot (*Chenopodium ficifolium* Sm.)	Ethanol extract (5000 mg mL-1)	86% control of aphid (*Aphis gossypii* Glover) Methanol extract (5000 mg mL-1) 83% control of aphid (*Aphis gossypii* Glover) n-Hexane extract (5000 mg mL-1) 54% control of aphid (*Aphis gossypii* Glover) Acetone extract (5000mg mL-1) 47% control of aphid (*Aphis gossypii* Glover)	Dang *et al.*, 2010
Eucalyptus	Oil volatiles	Reduction in male (78%) and	St Pathak and

Allelopathic source	Application mode/rate	Insect suppression	Reference
(*Eucalyptus camaldulensis* L.)		female (66.67%) adults of *Corcyra cephalonica*	Krishna,1991
Neem	Seed kernels water extract (2%)	Reduction in flower thrip (*Taeniothrips sjostedti* Trybom) (54%) and pod borer (*Heliothis armigera* Hb.) (32%) incidence	Hongo and Karel,1986
Neem (*Azadirachta indica* L.) St Seed crude extract	Oil volatiles	Reduction in male (26%) adults of *Corcyra cephalonica*, 93-100% mortality of adult *Macrotermes* termites	Jembere *et al.*, 2005

Mechanisms Underlying Allelopathy

- **Root Exudation:** Plants release allelochemicals into the soil, suppressing pathogens and pests.
- **Volatilization:** Airborne compounds repel insect pests or prevent fungal spore spread.
- **Decomposition:** Breakdown of allelopathic plant material releases compounds that inhibit harmful organisms.
- **Toxin Release via Wounding:** Damaged plants may release defensive allelochemicals, such as nicotine in tobacco (*Nicotiana tabacum*), to deter herbivores.

Benefits of Allelopathy

- **Reduced Chemical Dependency:** Minimizes pesticide and herbicide use, reducing environmental pollution and costs.
- **Sustainable Farming:** Supports organic farming and Integrated Pest Management (IPM) practices.
- **Soil Health Improvement:** Enhances soil fertility and structure through crop rotations and intercropping.
- **Lower Resistance Development:** Unlike synthetic chemicals, allelopathic compounds reduce the risk of resistance in pests and pathogens.

Future Prospects and Limitations of Allelopathy in Pest and Disease Management

Allelopathy offers a sustainable alternative for pest and disease control by utilizing natural plant-derived chemicals. Key future applications include:

- **Bioherbicides & Biopesticides:** Natural allelochemicals (e.g., phenolics, flavonoids) can be formulated for eco-friendly pest control.
- **Genetic Engineering:** Enhancing allelopathic traits in crops to suppress weeds and repel pests.
- **Companion Planting:** Using allelopathic plants (e.g., marigolds for nematodes, garlic for fungi) in pest management.
- **Cover Crops & Green Manure:** Crops like rye and sorghum release allelochemicals that control weeds and pathogens.
- **Nanotechnology:** Encapsulation of allelochemicals for targeted, prolonged pest control.

Limitations & Challenges

- **Variability:** Allelopathic effects can be inconsistent due to environmental factors.
- **Non-Target Effects:** Potential toxicity to beneficial organisms and soil microbes.
- **Stability Issues:** Rapid degradation reduces long-term effectiveness.
- **Research Gaps:** More studies are needed on mode of action, dosage optimization and ecological safety.

Despite these challenges, integrating allelopathy with biological control and organic farming holds great promise for sustainable pest management.

Conclusion

Allelopathy offers a promising natural strategy for pest and disease management, contributing to sustainable and eco-friendly agriculture. By leveraging plant chemical interactions, we can reduce synthetic chemical use, improve crop health and support biodiversity. As research progresses, allelopathy could play an increasingly significant role in modern farming practices, fostering a more resilient agricultural system.

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Strawberry Cultivation Boosting Rural Economies

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Introduction

Strawberries are a popular fruit enjoyed worldwide and their demand continues to rise. This high demand translates into attractive market prices, making strawberry cultivation a lucrative option for farmers. Rural economies often rely heavily on agriculture and the search for high-value crops that can boost income and create employment is a constant effort. In recent years, strawberry cultivation has emerged as a promising avenue for rural farmers, offering the potential for significant economic growth and empowerment. Strawberries, with their vibrant colour, sweet taste and high nutritional value, have become a popular fruit worldwide.Beyond their diet appeal, strawberries offer a significant opportunity for economic growth, particularly for rural farmers. Agricultural experts report that farmers are planting more acres of strawberries to fill the growing worldwide demand for the world's 19th most popular fruit.

Global production

Based on FAO reports, the worldwide production of strawberries exceeded 9.18 million tonnes in 2021. Asia is the largest continental producer (4.53 million tonnes) followed by America (2.18 million tonnes), Europe (1.76 million tonnes), Africa (634.29 thousand tonnes) and Oceania (60.31 thousand tonnes; FAO, 2023). The production of strawberries has historically been increasing, but in 2020, a reduction of 2% was observed, compared to 2019 data (Sources: Zacharaki *et al.*, 2023).

Regional production

Asia is the largest continental producer of strawberries, followed by America, Europe, Africa and Oceania.

Production by country

China is the world's largest producer of strawberries, followed by the United States and Turkey.

Production in India

In 2019, India produced 5,000 tons of strawberries (Source: CEIC Data, an ISI Emerging Markets Group Company 2012-2019 report). In 2020-2021, India's strawberry cultivation area was 3,031 hectares, producing approximately 19,840 metric tons (Source: Department of Agriculture and Cooperation, CEIC).

Production trends

Strawberry production has historically increased, but in 2020, production decreased by 2% due to the COVID-19 pandemic and labour availability and cost challenges (Sources: Zacharaki *et al.*, 2023).

Production challenges

Compared to traditional crops, strawberries offer a higher return on investment, attracting farmers seeking to diversify their income streams and improve their livelihoods. Strawberries, with their appealing taste and nutritional value, have emerged as a high-value crop with the potential to significantly boost the economies of rural farming communities.

Their adaptability to various climates and soil types, coupled with a relatively short growing cycle, makes them an attractive option for small-scale farmers looking to diversify their income streams. Moreover, the relatively short growing cycle of strawberries allows for multiple harvests in a year, further enhancing their profitability.

This article explores into the cultivation of strawberries and its potential to boost rural economies, focusing on the benefits, disease management, post-harvest handling, challenges and strategies for success.

Strawberry farming presents several advantages for rural farmers

- **High Profitability:** Strawberries command a high market price, offering farmers a potentially lucrative income source.
- **Short Growing Cycle:** Strawberries have a relatively short growing cycle, allowing for multiple harvests in a year and quicker returns on investment.
- **Diversification:** Integrating strawberr-ies into existing farming systems can diversify income streams and reduce reliance on traditional crops.
- **Job Creation:** Strawberry cultivation can generate employment opportunities in rural areas, particularly during harvesting and processing seasons.
- **Value Addition:** Strawberries can be processed into various products like jams, juices and desserts, increasing their market value and profitability

Cultivation Techniques

Strawberries are adaptable to various climates and soil types, making them suitable for cultivation in different regions. Modern farming techniques, such as protected cultivation in greenhouses or poly tunnels, allow for year-round production, even in areas with harsh weather conditions. These methods also improve yield and quality, ensuring a consistent supply of high-grade strawberries to meet market demands. Furthermore, the adoption of sustainable farming practices, such as integrated pest management and water conservation techniques, ensures the long-term viability of strawberry cultivation and minimizes its environmental impact.

- **Site Selection:** Strawberries thrive in well-drained, fertile soil with ample sunlight.
- **Variety Selection:** Choosing the right strawberry variety depends on climate, soil type and market demand.
- **Planting and Care:** Proper planting techniques, irrigation, fertilization and pest control are crucial for healthy growth and high yields.
- **Harvesting and Post-Harvest Handling:** Timely harvesting and appropriate post-harvest handling are essential to maintain fruit quality and extend shelf life.

Economic Impact

The economic benefits of strawberry cultivation extend beyond the individual farmers. The industry creates a ripple effect, generating employment opportunities in related sectors such as packaging, transportation and marketing. The increased income in rural areas also stimulates local businesses, leading to the development of infrastructure and impr-oved living standards. Moreover, the success of strawberry farming can attract investment in rural communities, further boosting economic growth and develop-ment.

- **Increased Income:** Higher incomes for farmers lead to improved living standards, better access to education and healthcare and reduced poverty.

• **Infrastructure Development:** The growth of strawberry farming can stimulate infrastructure development, including roads, irrigation systems and cold storage facilities.

• **Diversification of Income:** By incorporating strawberries into their farming systems, rural farmers can reduce their reliance on a single crop, thereby mitigating the risks associated with market fluctuati-ons or crop failures.

• **Rural Development:** Increased economic activity can revitalize rural areas, attracting new businesses and investments.

• **Empowerment of Women:** Strawberry farming is labour-intensive, creating employment opportunities for rural communities, particularly during harvesting and processing seasons.

Social Impact

Strawberry cultivation can have a significant social impact on rural communities. It provides opportunities for women and young people to engage in income-generating activities, empowering them and improving their social standing. The formation of farmer cooperatives and self-help groups facilitates knowledge sharing, access to credit and collective bargaining power, further strengthening the economic position of small-scale farmers. Additionally, the success of strawberry farming can lead to improved access to education, healthcare and other essential services in rural areas.

Pest and Disease Management

Strawberries are susceptible to various pests and diseases, requiring careful monitoring and timely intervention. Strawberry cultivation can be affected by several diseases, which can significantly impact yield and fruit quality. Here are some common diseases and their manage-ment strategies:

Fungal Diseases

Gray Mold (Botrytis cinerea): This is a common disease that causes fruit rot, especially during cool, wet conditions. It can also affect blossoms and leaves.

Management

• Practice good sanitation by removing infected plant material and debris.

• Promote air circulation by spacing plants properly and avoiding overhead irrigation.

• Apply fungicides at bloom and during fruit development, especially if wet conditions persist.

Powdery Mildew (Sphaerotheca macularis): This disease affects all above-ground parts, causing leaves to curl upwards and develop a white powdery growth.

Management

• Plant resistant varieties if available.

• Ensure good air circulation.

• Apply fungicides when symptoms appear

Leaf Spot (Mycosphaerella fragariae): This disease causes dark spots on leaves and can lead to defoliation in severe cases.

Management

• Remove infected leaves.

• Practice crop rotation.

• Apply fungicides as needed.

Red Stele (Phytophthora fragariae): This soil-borne disease affects the roots, causing them to turn reddish-brown. It can lead to plant wilting and death.

Management

• Plant resistant varieties.

• Improve soil drainage.

• Avoid overwatering.

Bacterial Diseases

Angular Leaf Spot (Xanthomonas fragariae): This bacterial disease causes small, water-soaked lesions on leaves, which can enlarge and become angular.

Management

• Use disease-free plants.

• Avoid overhead irrigation.

• Apply copper-based bactericides if necessary.

Other Diseases

• **Anthracnose:** This fungal disease can cause fruit rot and leaf spots.

• **Verticillium Wilt:** This soil-borne fungal disease can cause plant wilting and death.

General Disease Management Strategies

• Plant disease-resistant varieties when available.

• Practice crop rotation to break disease cycles.

• Maintain good sanitation by removing infected plant material and debris.

• Ensure proper spacing between plants to promote air circulation.

• Avoid overhead irrigation to reduce leaf wetness.

• Monitor plants regularly for symptoms of disease.

• Apply fungicides or bactericides as needed, following label instructions.

Vitamins and Minerals

• **Vitamin C:** Strawberries are an excellent source of vitamin C, a powerful antioxidant that supports immune health, collagen production and wound healing.

• **Manganese:** This essential mineral plays a role in bone health, metabolismand antioxidant defence.

• **Folate:** Also known as vitamin B9, folate is important for cell growth and development, especially during pregnancy.

• **Potassium:** This electrolyte helps regulate blood pressure, muscle contractions and nerve function.

Antioxidants

• **Anthocyanins:** These pigments give strawberries their vibrant red colour and have potent antioxidant properties, protecting cells from damage and reducing the risk of chronic diseases.

• **Ellagic Acid:** This polyphenol has antioxidant and anti-inflammatory effects, potentially reducing the risk of cancer and heart disease.

• **Quercetin:** This flavonoid has anti-inflammatory and antihistamine properties, supporting immune health and reducing allergy symptoms.

Other Nutrients

• **Fiber:** Strawberries are a good source of fiber, promoting healthy digestion, regulating blood sugar levels and supporting weight management.

• **Low in Calories and Sugar:** Strawberries are naturally low in calories and sugar, making them a guilt-free treat for those watching their weight or managing diabetes.

Health Benefits

• **Heart Health:** The combination of antioxidants, fiber and potassium in strawberries supports cardiovascular health by reducing blood pressure, improving choles-terol levels and preventing plaque buildup in arteries.

• **Cancer Prevention:** The antioxidants in strawberries may help protect against certain types of cancer by neutralizing free radicals and reducing inflammation.

• **Brain Health:** Studies suggest that consuming strawberries may improve cognitive function and reduce the risk of age-related cognitive decline due to their antioxidant and anti-inflammatory properties.

• **Immune Support:** The high vitamin C content in strawberries strengthens the immune system, helping the body fight off infections and illnesses.

• **Digestive Health:** The fibre in strawberries promotes healthy digestion, prevents constipation and supports a healthy gut microbiome.

Incorporating Strawberries into Your Diet

• Enjoy them fresh as a snack or dessert.

• Add them to smoothies, yogurt or cereal.

• Use them in salads or as a topping for grilled meats.
• Bake them into muffins, pies or tarts.

Challenges and Future Prospects

strawberry cultivation offers numerous benefits, it also presents certain challenges. These include the need for technical knowledge and skills, access to quality planting material and the risk of pest and disease outbreaks. However, with proper training, support from agricultural experts and the adoption of best practices, these challenges can be overcome. The future of strawberry cultivation in rural economies looks bright, with ongoing research and development leading to improved varieties, more efficient farming techniques and better market access. By embracing innovation and sustainability, rural farmers can continue to reap the sweet rewards of strawberry farming, contributing to their economic prosperity and the overall development of their communities.

• **High Initial Investment:** Setting up a strawberry farm can require significant upfront investment in land, planting material and infrastructure.
• **Pest and Disease Management:** Strawberries are susceptible to various pests and diseases, requiring effective management strategies.
• **Market Volatility:** Strawberry prices can fluctuate depending on supply and demand, impacting farmers' income.
• **Climate Change:** Extreme weather events and changing climate patterns can affect strawberry yields and quality.

Post-harvest Losses and Management of Strawberries

Strawberries are highly perishable fruits, making them susceptible to post-harvest losses. These losses can occur due to various factors, including:

• **Physical damage:** Bruising, crushing and cuts during harvesting, handling, and transportation.

Fig. Packaging of 100% Ripped fruit

• **Physiological changes:** Respirat-ion, water loss and ripening continue after harvest, leading to quality deterioration.
• **Microbial decay:** Fungal and bacterial infections, such as graymold (Botrytis cinerea) and Rhizopus rot, can cause significant losses.
• **Environmental factors:** Temperature fluctuations, humidity and exposure to ethylene gas can accelerate spoilage.

Management strategies to minimize post-harvest losses in strawberries

1. Pre-harvest practices

- **Proper cultivar selection:** Choose cultivars with good post-harvest characteristics, such as firmness and resistance to diseases.
- **Field sanitation:** Remove diseased and damaged fruits from the field to reduce the source of infection.
- **Optimal harvest time:** Harvest strawberries at the appropriate maturity stage, typically when they are three-quarters red. Avoid harvesting overripe or damaged fruits.

2. Harvesting and handling

- **Gentle harvesting:** Handle strawberries carefully to avoid bruising and other physical damage.
- **Harvest during cool hours:** Harvest in the early morning or late afternoon

when temperatures are cooler.

- **Use appropriate containers:** Use shallow containers to prevent crushing of the berries.
- **Prompt cooling:** Cool strawberries as soon as possible after harvest to slow down respiration and decay.

3. Storage and transportation

- **Maintain cold chain:** Store and transport strawberries at low temperatures (0-4° C) to maintain quality.
- **Control humidity:** Maintain high humidity (90-95%) to prevent water loss and shrivelling.
- **Modified atmosphere packaging:** Use modified atmosphere packaging with high carbon dioxide levels to reduce respiration and decay.
- **Proper ventilation:** Ensure proper ventilation to prevent the buildup of ethylene gas, which can accelerate ripening.

4. Post-harvest treatments

- **Fungicide treatments:** Apply approved fungicides to control fungal diseases, such as graymold.
- **Irradiation:** Use irradiation treatment to reduce microbial load and extend shelf life.
- **Edible coatings:** Apply edible coatings to create a protective layer and reduce water loss.

5. Quality control

- **Sorting and grading:** Remove damaged and diseased fruits before packing.
- **Regular inspection:** Inspect stored strawberries regularly for signs of spoilage
- **Proper labelling:** Label packages with information on harvest date, storage conditions and quality grade.

By implementing these management strategies, growers and handlers can significantly reduce post-harvest losses in strawberries and ensure that consumers receive high-quality fruits.

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Applications of DSSAT Modelling for Crop Yield Prediction and Management in Maize

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Introduction

The modeling of the Decision Support System for Agrotechnology Transfer (DSSAT) has effectively been utilized in forecasting and overseeing maize crop yields in various agricultural settings. For example, empirical research has illustrated that modifications in sowing dates considerably affect maize yield, with the optimal sowing period identified as being between November 1 and November 15, resulting in enhanced yields attributable to favorable conditions of rainfall, solar radiation and a reduction in pest prevalence. Also, the unification of remote sensing datasets with DSSAT has significantly heightened the fidelity of yield forecasts, achieving a correlation of 94.19% between expected and actual yield performances. Additionally, DSSAT has been utilized to evaluate nitrogen management strategies, uncovering that certain practices can optimize both growth and yield while accurately modeling nitrogen dynamics. Thanks to its ability to replicate various farming methods and climate factors, the DSSAT modeling provides crucial benefits in overseeing and anticipating maize crop production. Furthermore, while positive outcomes have been observed, changes in climate variables such as temperature and solar radiation have also exhibited adverse effects on maize yields, underscoring the model's utility in forecasting and strategizing for impending agricultural challenges (Yahaya *et al*., 2025).

The DSSAT modeling framework, with its capacity to emulate diverse agricultural methods and climate conditions, is highly valuable for managing and predicting maize crop yields. This modeling instrument facilitates a comprehensive understanding of fertilizer management, optimization of sowing dates and climate influences in order to enhance maize production.

Sowing Date Optimization

The optimizing sowing dates or planting times shows more impact on crops especially maize yields. It have been examined from the experimentation the results shows that crop sowing between November 1 and November 15 maximize yields compared to the crops sowing earlier than sowing window or on later on dates because of best rainfall pattern and solar radiation conditions (Li *et al*., 2024). In addition to this optimum sowing dates enhance the crop yields with efficient resource utilization and enhance resilience to climatic pattern. Among different models this model proved to be reliable and flexible in yield forecasting by showing a major association between expected and actual yields.

Nutrient Management

One of the valuable tools for managing nutrient in crop especially maize is the Decision Support System for Agro technology Transfer (DSSAT). This model enables users to model crop growth, nutrient uptake and the effects of various management techniques. This helps farmers, researches to optimize the amount of fertilizer application and boost up the crop yields. The combined application of inorganic and organic fertilizers, along with NPK+FYM, has confirmed a 20% improvement in maize production with DSSAT model over 25 years period, highlighting the model's significance in sustainable farming methods (Sridevi *et al.*, 2024). Additionally, this model effectively simulate nitrogen dynamics, helping to assess the impact of various levels of nitrogen management strategies on maize growth, yield attributes and yield (Kumar *et al.*,2024).

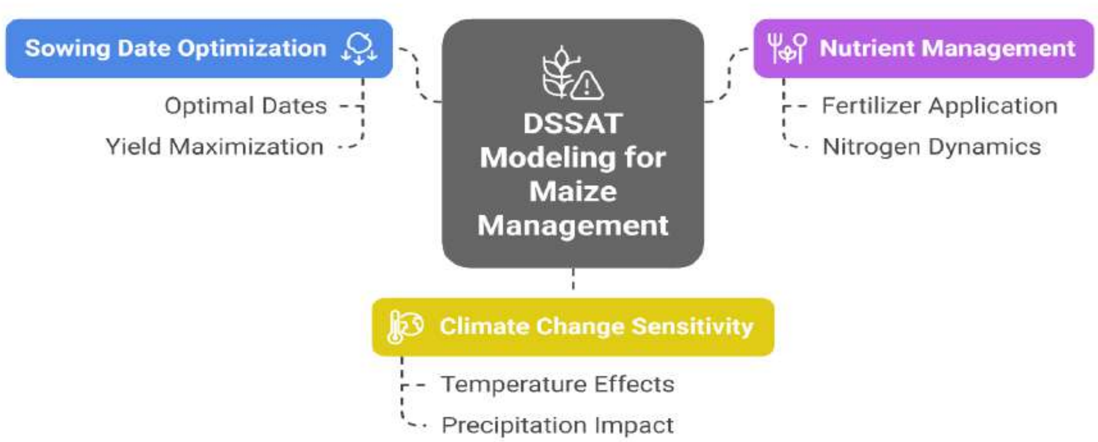
Climate Change Sensitivity

The Decision Support System for Agrotechnology Transfer (DSSAT) is dynamic simulation models that simulate cell division and cell enlargement results in crop growth and development which results in yield under several climatic scenarios, including variations in temperature, precipitation and rise in CO_2 concentration, in order to evaluate how sensitive crops are to climate change. It also simulates soil water balance and soil nitrogen and carbon status. The effect of climate change on maize yields can be carried out using sensitivity assessment through DSSAT model (Yahaya *et al.*, 2025). According to the model, yields are harshly impacted by increasing or decreasing temperatures and solar radiation but they are positively correlated by precipitation. This information is important for farmers for the future plan in agriculture. The accuracy of projections in various agricultural contexts may be impacted by the variety of local variables and the possible constraints of model assumptions, even though DSSAT modeling provides reliable predictions and management techniques for maize crop output.

Conclusion

Decision Support System for Agrotechnology Transfer (DSSAT) is a model, is helpful in forecasting and controlling the yield in maize crop yields under diversified agro

Applications of DSSAT Modeling in Maize Crop Management



climatic circumstances. It is integration the data from remote sensing, sowing date's optimization and evaluation of nutrient management strategies. It facilitates precision and data-driven decision for maize cultivation and sustainable agriculture. It is evident from the experimentation that proved combining application of organic and inorganic fertilizers resulting in increasing nitrogen use efficiency (NUE) and crop productivity. In addition to that studies have shown that planting maize between November 1 and November 15 produces the best results due to favorable meteorological circumstances. Optimum Temperature, Solar radiation, humidity etc helps in improving metabolism of the crop which results in proper growth and development of the crop. Furthermore, sensitivity analysis shows that climate factors have a major effect on maize yields, highlighting the necessity of adaptive agricultural practices. The impact of localized factors and need for extensive data set, difficulty in handling and require skilled person in simulating certain environmental conditions are some of the drawbacks of DSSAT modeling, not with standing its efficacy. But the fact that the actual harvests match its excellent yield prediction accuracy highlights how reliable it is for farmers, researchers and policymakers. In order to boost maize production and to ensure food security in the face of climate change, agricultural stakeholders can use DSSAT to better predict obstacles, apply precision farming methods and create climate-resilient strategies.

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Functional Properties of Mozzarella Cheese

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Introduction

Cheese, a highly nutritious and palatable food, is of significant value in the diet since it comprises of almost all of the protein, fat, essential minerals, vitamins and other nutrients. Cheese is primarily used for its organoleptic contribution to food; however, it provides nutrition and functionality to an array of foods. As an ingredient in food system, cheese is expected to exhibit functional characteristics in the raw (e.g., slice ability, shred ability, grate ability) and cooked (e.g., flow ability, mouth feel, flavor and/or stretch ability) forms (Rohit and Metzger 2008).There is a growing demand for cheeses and/or cheese toppings possessing customized functional attributes in the pizza, burger and sandwich trade (Atanu 2001). Since cheese is an integral part of food products, it is becoming increasingly important for the cheese manufacturers to produce their cheese according to the functionalities required for the end use (Atanu 2001). Cheese is an extremely versatile food product that has a wide range of flavors, textures and end-uses. The physical properties of cheese are largely determined by the casein content, the type, number and strength of case in interactions, proximate cheese composition and ripening conditions (Lucey *et al.,* 2003; Banville *et al.,* 2013). Sensory evaluation of cheese presents a considerable challenge since there are numerous cheese varieties. The modern consumer is more affluent and aware of nearly all aspects of cheese quality. Thus to survive in the competitive market, the manufacturer must control the cheese characteristics by evaluating the pertinent properties and understanding how such characteristics are influenced by a range of factors.

Cheese is an extremely versatile food product that has a wide range of flavor, textures and end uses. The vast majority of cheese is eaten not by itself, but as part of another food. As an ingredient in foods, cheese is required to exhibit functional characteristics in the raw as well as cooked forms. Melting, stretching, free-oil formation, elasticity and browning are the functional properties considered to be significant for Mozzarella cheese. When a cheese is destined for its end use, some of its unique characteristics play a significant role in the products acceptability. For instance pH of cheese determines the cheese structure which in turn decides the cheese shred ability and melt ability properties. The residual galactose content in cheese mass determines the propensity of cheese to brown during baking. Development of 'tailor-made cheese' involves focusing on manipulation of such unique traits of cheese in order to obtain the desired characteristics for its end use application suiting the varied consumer's whims and wishes.

Definition of Cheese

Cheese is the fresh or matured solid or semi-solid product obtained:

- By coagulating milk, skim milk or partly skimmed milk, whey, cream or butter milk or any combination of these materials, through the action of rennet or other suitable coagulating agents and by partially draining the whey resulting from such coagulation.
- By processing techniques involving coagulation of milk and/or materials obtained from milk (provided that the whey protein casein ratio does not exceed that of milk) and which give an end product which has similar physical, chemical or organoleptic characteristics as the product defined under.

Types of cheeses

More than 400 different varieties of cheese are available worldwide (National Dairy Council 2000). However, the cheeses are classified (Table 1) into specific categories based on several criteria like firmness (moisture content), type of culture, ripened or otherwise, etc. (Fox *et al.*, 2016).

Table 1 Classification of cheese based on hardness/moisture content.

Cheese type	Moisture content (%)	Examples
Soft cheese	50–80	Cottage, Quark, Baker's, Mozzarella, Camembert, Feta
Semi-soft cheese	39–50	Blue, Limburger, Provolone, Tilsiter
Hard cheese	Max.39	Cheddar, Colby, Edam, Swiss, Gouda
Very hard cheese	Max.34	Parmesan, Romano, Sardo, Grana

(**Source:** Olson (2008) and Fox *et al.*, (2016)

Functionality of cheeses

The term 'functionality' for cheese refers to 'capable of performing'. It is applied to wide varieties of cheese; the characteristics of significance include flavor, physical properties and stability. When a cheese is destined for its end use, some of its unique characteristics play a significant role in the products acceptability. Development of 'tailor-made cheese' involves laying a stress on manipulation of such unique traits of cheese in order to obtain the desired characteristics for its enduse application. Thedefinition of terms related to cheese functionality is provided in Table 2

Table 2 Definition of terms related to cheese functionality.

Cheese Functionality	Definition
Melting	Liquefaction of cheese by heat
Stretching	Formation of fibrous strands that elongate without breaking yet resist permanent elongation
Oiling-off	Tendency of free oil separation from melted cheese. Such property is also referred to as fat leakage
Cook colour/ Browning/ Blistering	Blisters are trapped pockets of heated air and steam that may be preferentially scorched during baking. It occurs at the cheese surface during high temperature bakin

Cheese Functionality	Definition
Whitening/ Decolourization	Bleaching of cheese
Spreadability	Ability to spread over a surface on application of slight force to form a layer, thin enough to form a coating
Grating	Property of cheese to be divided into small particles on rubbing
Slicing	Property of cheese to be divided into slices or blocks
Dicing	Property which enables user to cut cheese into cubes
Shredding/ Mincing	Property enabling cheese to cut or chop into very small pieces

(**Source:** Guinee (2002), Childs *et al.,* (2007) and Rohit and Metzger (2008)

Mozzarella cheese

Mozzarella cheese belongs to a class of 'Pasta filata' family which involves the principle of skilful stretching of the curd in hot water to obtain smooth texture in cheese. The cheese is soft, white, unripened, that may be consumed shortly after manufacture. The specific melting and stretching characteristics of Mozzarella cheese is highly appreciated in the manufacture of Pizza in which it is a key ingredient (Atanu 2001). The flow chart for the production of Mozzarella cheese by 'Starter culture' and 'Direct acidification' methods is depicted in Fig.1. This cheese's clean, mild flavor, shred ability and appealing melt and stretch make it ideal for pizza. Low moisture part-skim Mozzarella (LMPSM) finds greater application than traditional Mozzarella (up to 60% moisture) on pizza owing to its superior slicing qualities. LMPSM is associated with a moisture content ranging from 45 to 52% and a fat on dry matter (FDM) content ranging from 30 to 45% (Jana and Mandal 2011). Such lower moisture content of LMPSM confers superior shred ability and the moderate fat content provides desired fat leakage during its baking applications. The composition of Mozzarella cheese reported in literature is depicted in Table3.

Table 3 Proximate composition of Mozzarella cheeses

Constituents	Composition of Mozzarella cheese
Moisture,%	49.21
Fat,%	26.17
Total protein,%	22.32
Lactose,%	-
Ash,%	4.51
Acidity, %LA	-

Effect of starter cultures

Different starter cultures have varying proteolysis activity can influence the functionality of Mozzarella cheese (Hong *et al.*, 2001). Lactobacillus helveticus when used as adjunct starter with Streptococcus thermophilus is reported to provide superior functional properties (especially melt) compared to use of Lb. delbrueckii ssp. bulgaricus (Oberg *et al.*, 1991b). Mozzarella cheese, aged 1 month, prepared using mixed culture (S. thermophilus and Lb. helveticus) exhibited 3-4 times greater melt ability (compared to fresh cheese) as against only 2 times greater meltability of cheese made using S. thermophilus culture singly (Dave *et al.*, 2003a). The synergistic effect between coagulating enzyme and starter culture is reported to enhance the melt and flow properties of Mozzarella cheese (Dave *et al.*, 2003b).

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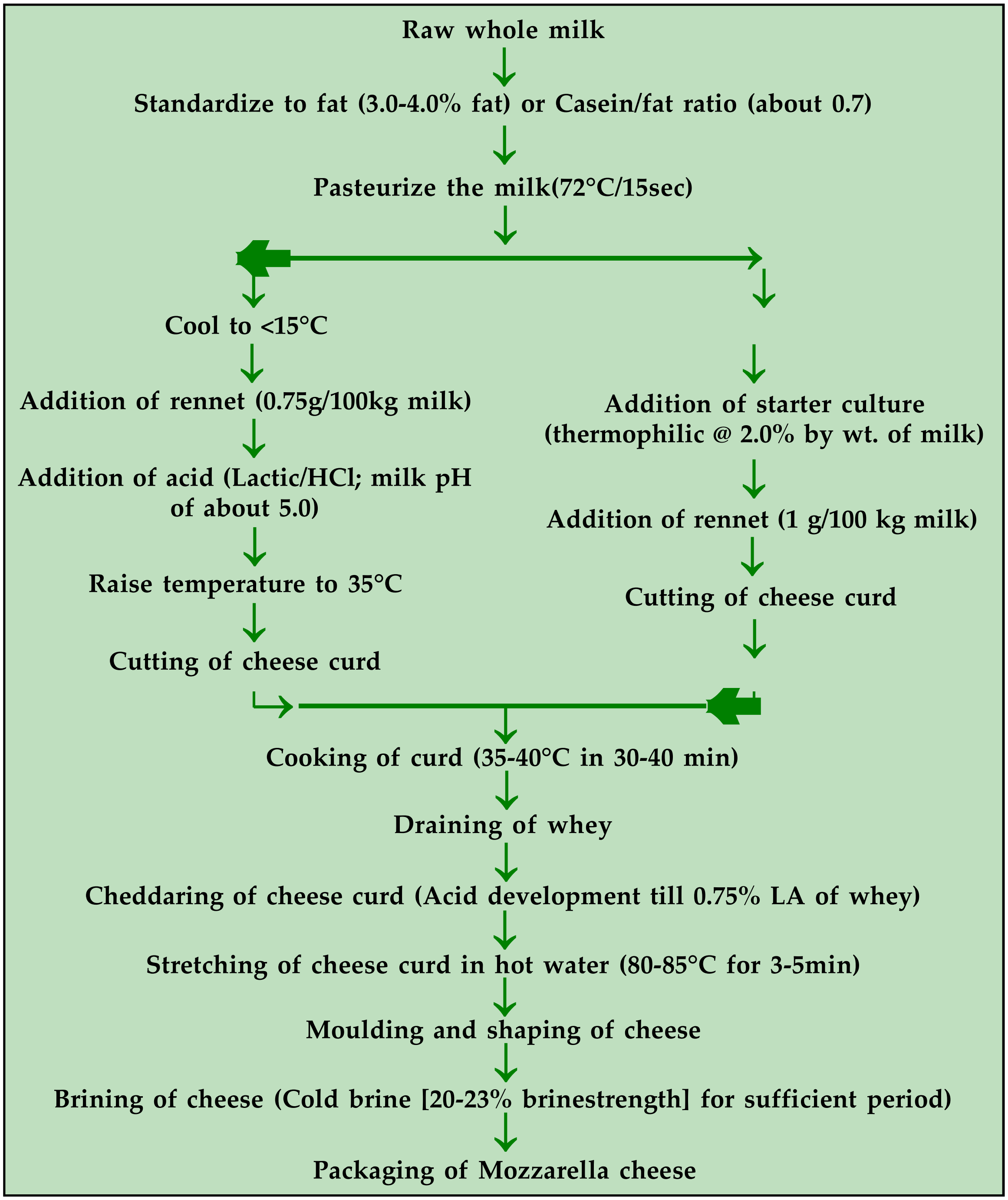
Flow chart for preparation of Mozzarella cheese



Effect of rennet

Different coagulating enzymes are known to have different specificity towards casein (Chaves and Grosso 1999). Protease from Cryphonectria parasitica is more proteolytic and specific towards b-casein compared to chymosin; the latter is less proteolytic and more specific towards as-casein. The highest percentage breakdown of as-casein was * 75% in 1 month old Mozzarella cheeses made with mixed culture using chymosin rennet, while breakdown of b-casein was * 50% in similar aged cheese prepared utilizing rennet from Crypho-nectria parasitica. The meltability of Mozzarella cheese was reported to correlate mainly with the hydrolysis of b-casein (Dave *et al*. 2003a).

pH of curd (at milling) and cheese

The pH at whey drain has a profound impact on curd functionality than the pH at milling, since the former pH is critical in deciding the amount of lactose partitioned into the curd (Yun *et al.* 1993a). Mozzarella cheese characteristics in melted state such as melt ability and free oil formation were unaffected by varying the milling pH in the range 5.1 to 5.4. (Maldonado *et al*. (2013) reported that the optimum condition for Mozzarella cheese curd melting and stretching was adjusting the final curd pH in the range 5.2–5.5. Cheeses stretched at pH 5.2 and 5.3 were criticized fo being sticky and easily chewable, not springy and having low disintegration. However, cheeses stretched at pH 5.6 and 5.7 were firm, springy and chewier (Maldonado *et al*. 2013).

Conclusion

Changing habits of diet and use of newer appliances for cooking and processing of cheese product demands specific tailor-made functionalities expected from such cheese product. Cheese making has changed from a closely guarded craft to science because of better understanding and advances in the fields of chemistry, technology and bacteriology of milk and cheese. Thus, today's cheese maker is in a better position to exploit such knowledge in producing 'tailor-made' cheese product, suiting the consumer's whims and wishes. The pizza maker should specifically use the Mozzarella cheese that has been aged for 1–1.5 weeks to permit improvement in the melting and stretching properties of cheese suitable for its end use on pizza. Developing accurate tests to evaluate the functional properties of cheese and correlating such data with the varying end-use applications for cheese is the need of the day.

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Indeterminate Tomato Cultivation in Shadenet House

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Introduction

Tomato (*Solanum lycopersicum*), a major vegetable crop globally, is highly valued for its culinary versatility, nutritional content and market demand. Tomatoes originated in South America and were later introduced to Europe and Asia. They were initially considered poisonous in some regions before gaining popularity. Tomatoes are a globally cultivated vegetable, crucial for various food products, including sauces, canned goods, and fresh consumption. They are typically grown in tropical and subtropical regions, requiring well-drained soil and adequate sunlight and water. The tomato is a plant whose fruit is an edible berry that is eaten as a vegetable. The tomato is a member of the nightshade family that includes tobacco, potato and chili peppers. It originated from and was domesticated in western South America. It was introduced to the Old World by the Spanish in the Columbian exchange in the 16th century. Tomato plants are vines, becoming decumbent and can grow up to 3 m (9.8 ft); bush varieties are generally no more than 100 cm (3 ft 3 in) tall. They are tender perennials, often grown as annuals.

Tomato plants are dicots. They grow as a series of branching stems, with a terminal bud at the tip that does the actual growing. When the tip eventually stops growing, whether because of pruning or flowering, lateral buds take over and grow into new, fully functional, vines. Tomato vines are typically pubescent, meaning covered with fine short hairs. The hairs facilitate the vining process, turning into roots wherever the plant is in contact with the ground and moisture, especially if the vine's connection to its original root has been damaged or severed. The leaves are 10–25 cm (4–10 in) long, odd pinnate, with five to nine leaflets on petioles, each leaflet up to 8 cm (3 in) long, with a serrated margin; both the stem and leaves are densely glandular-hairy. Tomatoes can exhibit either determinate or indeterminate growth habits. Indeterminate tomatoes continue growing and producing fruit throughout the growing season, unlike determinate varieties that finish their fruiting cycle after a certain period. They are vining plants, requiring support structures like cages or stakes to prevent them from sprawling. Indeterminate varieties offer a longer harvest period, allowing gardeners to enjoy fresh tomatoes for an extended duration.

Methodology

The cultivation of indeterminate tomato in a shade net house involves several key steps to optimize plant health and productivity:

1. Shadenet House Preparation: A 50% green shadenet was installed to reduce solar radiation and heat stress. Raised beds of 1 meter width and 30 cm height were prepared and sterilized using formalin (2%) to prevent soil- borne diseases.

2. Seedling Production: Seeds of indeterminate hybrid tomato were sown in protrays using a sterile growing media (coco peat, vermiculite and perlite). After germination, seedlings were maintained in a nursery for 25-30 days. Adequate light, water and nutrients were supplied to develop healthy transplants.

3. Transplanting: Seedlings were transplanted in rows with spacing of 60 cm x 45 cm on raised beds covered with black plastic mulch. Drip irrigation was installed with inline drippers at 30 cm spacing to ensure uniform water supply.

4. Training and Pruning: Plants were trained vertically using bamboo poles and nylon wires. Lateral branches were regularly pruned to maintain a single stem system and improve light penetration and air circulation.

5. Fertigation: Water-soluble fertilizers were applied through the drip system. The fertigation schedule was adjusted according to crop growth stages, with higher nitrogen in vegetative stages and increased potassium during fruiting.

6. Pest and Disease Management: Regular monitoring and use of yellow sticky traps, neemoil sprays and biopesticides helped control common pests like whitefly and thrips. Fungal diseases were managed with copper-based fungicides and cultural practices.

7. Harvesting: Harvesting began around 65-70 days after transplanting and continued over an extended period due to the indeterminate growth habit.

Results

The cultivation of indeterminate tomato under shadenet conditions showed the following outcomes:

Parameter	Observation	Remarks
Plant Height	180 - 200 cm	Healthy vertical growth
Days to First Flowering	28 - 32 days	Early flowering observed
Fruiting Period	More than 100 Day's	Extended harvest window
Yield per Plant	10 - 14 kg	High productivity
Fruit Quality	Firm, uniform, red	Suitable for fresh market
Pest Incidence	Low	Due to controlled Environment

Conclusion

Indeterminate tomato cultivation in shadenet houses offers significant advantages in terms of yield, quality, and marketability. The protected environment reduces abiotic stress and disease pressure, enabling better crop management. This method is especially beneficial for farmers targeting off-season production or high-value markets. Integration of fertigation, proper training and IPM practices further enhances profitability.

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Marigold: A Garden Staple for Farmers

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Introduction

Marigold is one of the most commonly grown flowers for garden decoration and extensively used as loose flowers for making garlands for religious and social functions. It has gained popularity amongst the gardeners because of its easy culture and wide adaptability. Its habit of free flowering, short duration to produce marketable flowers, broad spectrum of attractive colours, shape, size and good keeping quality has attracted the attention of flower growers. Marigold is ideal for cut flowers, especially for making garlands. They can be planted in the beds for mass display or grown in pots. The French Marigolds are suitable for hanging basket and edging.

Botanical Description

Marigolds, belonging to the genus Tagetes in the Asteraceae family, are herbaceous annuals or perennials with bright, yellow, orange or red composite flowers, often solitary or clustered and finely cut, opposite leaves. African marigold is a diploid species with 2n=24 chromosomes, while French marigold is a tetraploid with 2n=48.

General Characteristics

- **Family:** Asteraceae (Compositae)
- **Origin:** Native to Central and South America, particularly Mexico
- **Habit:** Annual herbs

- **Growth:** Erect, branched and bushy depending on the species
- **Leaves:** Pinnately divided, with leaflets that can be lanceolate or linear-lanceolate and serrated
- **Flowers:** Small to medium-sized, ranging in colour from yellow to orange to mahogany red and can be single, semi-double or double
- **Fruits:** Achenes

Climate: Marigold requires mild climate for luxuriant growth and flowering. The optimum temperature range for its profuse growth is 18-20°C. Temperatures above 35°C restrict the growth of the plants, which leads to reduction in flower size and number. In severe winter, plants and flowers are damaged by frost.

Soil: Marigold can be grown in a wide range of soils, as it is adapted in different soil types.

French (Dwarf) marigolds are best cultivated in light soil whereas rich well drained, moist soils are best suited for African (Tall) marigolds. Sandy loam soil with pH 7.0 to 7.5 is ideal for its cultivation.

Species and cultivar

1. *Tagetes erecta* (African marigold): Cultivating it for medicinal, ceremonial and decorative purposes. This plant reaches heights of between 50-110 cm. The colour range is from white and cream to primose, yellow, gold and orange.

2. *Tagetes patula* (French marigold): The flower is an annual, occasionally reaching 0.5 m by 0.3m. Stem is reddish in colour and the foliage is darker than African marigold. The colour of flower varies from yellow to red, either single or double and borne on proportionately long peduncle.

3. *Tagetes tenuifolia* (Syn. T. signata): It is a dwarf and bushy plant. Flowers have 5 rays, roundish and obovate with spicy flavour.

4. *Tagetes lucida* (sweet scented marigold): The plants are tender, perennial, leaves are sessile, small and lanceolated. Flowers are usually 2-3 rayed.

5. *Tagetes minuta* (wild marigold or mint marigold): tall, upright herb native to South America, now naturalized worldwide, with uses as a culinary herb, insect repellent and in traditional medicine.

Indigenous varieties of African Marigold

1. Pusa Narangi Gainda: Pusa Narangi Gainda is a hybrid variety of African marigold which was developed by the crossing of Crack Jack and Golden Jubilee. The plant of this variety is medium stature; grows a height of 80-85 cm. The plant remains vegetative for 100 days and flowers in 125-135 days. The flowering duration ranges from 45-60 days. The colour of flower is orange with big ruffled florets. The yield of variety 25-30 tonnes/ ha. This is an open pollinated variety and seed can be multiplied in farmer's field.

2. Pusa Basanti Gainda: Pusa Basanti Gainda is also a hybrid variety developed from IARI, New Delhi which was cross of Golden Yellow and Sun Giant. The plant of this variety is medium stature, which grows a height of 60-65 cm. the plant remains vegetative for 135 days and takes 140-145 days to flowers. The plant needs to pinch 45-50 days. The variety sown in October and transplanted during November. It is an open pollinated variety and yield up to 75-100 kg of seeds/ha.

3. Pusa Arpita: Pusa Arpita is a French marigold variety known for producing medium-sized, light orange flowers, particularly during mid-December to mid-February in the northern plains of India, with an average fresh flower yield of 18-20 tons/ha. The plant has dense foliage. It is also an open pollinated variety.

Land preparation

For the main field, the land should be ploughed well followed by 2-3 harrowing and mixing of FYM @ 20-25 t/ha should be incorporated to the soil. Make the ridges and furrow properly.

Propagation

There are two common methods of propagation of marigold i.e., by seeds and by cuttings. Plants raised from seeds are tall, vigorous and heavy yielder and hence, seed propagation is preferred to cuttings.

Nursery rising

• The marigold seeds are black in colour and remain viable for about 1-2 years for rising of seedlings,
• Seed germinates in 5-7 days. Before sowing the seeds should be treated with captan 2g/kg of seed to prevent damping off.
• Seeds should be sowed in pots, seed boxes or raised nursery beds.
• Nursery beds are prepared by digging area and incorporating well rotten FYM.
• Before sowing the seeds, the soils should be drenched with Captan to avoid the ants, which carry away the seeds.
• The nursery beds should be remained moist during entire period.
• The quantity of seed required depends upon the level of its purity and germination rate.
• Generally, 200-300g seed/acre is required for raising the nursery in summer and rainy season and 150-200g/acre for winter season.
• About 1.0-1.5 kg seeds is required for planting in one hectare whereas 250 g/ha is sufficient in case of F1 hybrid. Seed germinates in 5-7 days.
• The seed germinate 4-5 days after sowing and seedlings become ready for transplanting after 3-4 weeks for sowing.

Sowing time and season

Depending on environment, planting of marigold can be done in three seasons i.e., rainy, winter and summer and seeds are sown accordingly. Hence, flowers of marigold can be obtained throughout the year. The seasons of sowing and transplanting of seedling for obtaining flowers at different seasons of a year are as under:

Flowering seasons	Sowing time	Transplanting time
Late rains	Mid- June	Mid - July
Winter	Mid- Sep.	Mid - Oct.
Summer	Jan - Feb.	Feb. - March

Transplanting of seedlings

• Marigold seedlings are easily transplanted and established in the field without much mortality.
• At the time of transplanting, they should be stocky and bear 3-5 true leaves.
• Thin and long seedlings do not make a good plant.
• Transplanting should be done in well prepared land and soil is pressed around root zone to avoid air pocket
• After transplanting, a light irrigation or watering with rose cane should be done.
• Plant density depends largely upon the growth habit, cultivar and the soil type.
• In general, spacing should be 30 cm x 30 cm for French marigold and 40 cm x 40 cm for African marigold.
• Proper spacing between plants is required for better development of plant and higher flower yield.

Manure and fertilizers

Well decomposed FYM @ 24 t/ha should be mixed before ploughing. In addition, recommended N:P:K fertilizer dose would be 120:80:80. Half quantity of nitrogen and full of potash and phosphorus should be applied as basal dose, preferably one week after transplanting. The remaining quantity of nitrogen should be 30-40 days after transplanting. Marigold also requires zinc and boron for flower quality and yield.

Weeding

Weeds are a major problem in marigold especially in rainy season crop. If the weeds are not removed in time, a great loss would occur in terms of growth and productivity of marigold. During the entire growth 3-4 manual weeding are required. Weeding should be done as and when necessary.

Irrigation

Irrigation is done once in a week or as and when necessary. Water stagnation should be avoided. Irrigate the crop in 7-8 days interval, but the frequency and quantity of water also depend upon soil and season. In lighter soil, more frequent irrigation is required than that in heavy soil. In hot summer it requires irrigation after 4-5 days interval while at 10-12 days interval in winter months. Rainy season crops are irrigated according to the climate. Constant moisture supply is maintained from bud formation to harvesting of flowers.

Pinching/ nipping

1 month after transplanting the seedlings pinching is followed for bushy growth of the plant and development of lateral branches. Pinching is generally done for the 40 days after transplanting, late pinching at 50-60 days proved less effective for branching. Pinching results into production of a greater number of flowers.

Diseases management

Diseases	Symptoms	Managements
Damping of (*Rhizoctoniasolani*)	Brown necrotic spots on young seedlings	Proper drainage and ventilation, avoid over watering Drenching with copper oxychloride @3g/l
Collar rot (*Pythium* sp., *Phytophthora* sp. and *Sclerotium rolfsii*.)	Black lesions on main stem Rotting at the collar region	Crop rotation for 3-4 years. arbendazim @ 1g/l reduces the incidence of disease.
Alternaria leaf spot (*Alternaria tagetica, A. zinnia and A. alternate*)	Minute brown spot near the lower leaves and then progress upward.	Avoid overhead watering. Spraying of Dithane M-45 0.2% at fortnightly intervals from the first appearance of disease
Fusarium Wilt (*Fusarium oxysporum*)	Pale green leaves, wilting of plant.	Crop rotation Carbendazim (0.2%) is effective
Powdery mildew (*Oidium* sp. and *Leveillula taurica*)	It appears as grey or white powder. Leaves turn yellow and fall prematurely.	Kerathane (40 E.C) @ 0.5% or dusting sulphar powder at 15 days interval.

Pest management

Pest	Symptoms	Managements
Red spider mite (*Tetranychus* sp.)	They suck the plant sap.	Spraying of Kelthane (2 ml/l)
Hairy caterpiller (*Diacrisia oblique*)	Eat away the foliage.	Spray Carbaryl @ 2 ml/l
Aphid	Black or brown spot	Spraying of malathion or dimethoate at 2 ml/

Harvesting of Flowers

After transplanting plans take 40-50 days to flower. Loose flowers are plucked when attain full size depending upon the variety. Flowers should be harvested in the morning hours. Irrigation before plucking gives better flower quality. Plucking of flowers regularly and removal of dried flowers enhance the yield. For Garland stalk less fully opened flowers (loose flowers) are picked, white for vase decoration also fully opened flowers with stalk are plucked. Loose flowers are packed in a bamboo basket, while flowers with stalk are bunched in bundles and transported to market. From one plant near about 100 to 150 flowers are obtained. Blooming duration is near about 3 months.

Packing

After harvesting, it is better to keep flowers in cool place. The marigold is packed in gunny bags for local market and for distance market bamboo basket are used.

Harvesting

Use and profit Flowers should be harvested after they have completely bloomed. The best time to pluck flowers is morning or evening. Before plucking the flowers, the field should be lightly irrigated so that the freshness of the flowers remains.

Yield

African marigolds yield about 15-28 t/ha whereas the French marigold yields 10-12 t/ha.

Conclusion

Marigold cultivation is a highly rewarding and profitable venture, offering numerous

benefits to farmers, florists and industries. This vibrant and versatile flower is not only a popular ornamental crop but also a valuable source of carotenoids, xanthophylls and other bioactive compounds. Marigold cultivation requires minimal care and maintenance, making it an ideal crop for small-scale farmers and commercial cultivators. The crop is comparatively simple to grow and because of its hardiness, it may flourish in a range of soil types and climates. The demand for marigolds is high, driven by the floriculture industry, pharmaceutical applications, and food processing sectors. Marigold flowers are used in garlands, bouquets and other floral arrangements, while their extracts are used in cosmetics, medicines and animal feed.

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Women Entrepreneurship through Dairy Farming

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Introduction

The dairy development in terms of milk production witnessed regional variation in response to geographical size, population, nature and stages of agricultural development and degree of demand for livestock products mainly milk and meat. The growth and development of dairy in India took place in sequential efforts of the government in both during pre and post-independence period. History of dairy development in India can be divided into two distinct phases: pre and post-Operation Flood. The first dairy farm was set up in Allahabad in 1913, followed by Bangalore, Ooty and Karnal. These farms were well maintained and used improved milch animals. The onset of the Second World War gave momentum to private dairies with some modernized processing facilities.

Uttar Pradesh is the leading state not only in population and area but also in milk production and livestock population. Dairy farming is expected to have tremendous oppo-rtunities for development of farmers, labourers and women. In total it is one of the most important sources of rural transformation. Dairy farming is the best tool for poverty alleviation and doubling of farmer's income as well as to achieve self-reliance in rural areas.

A large number of innovative schemes were introduced time to time by respective central and state governments for successive improvement in this sector of economy. Govt. of India is making efforts for strengthening infrastructure for production of quality milk, procurement, processing and marketing of milk and milk products through different Dairy Development Schemes. Establishment of new processing units for dairy products; packaging, preservation, cold chain logistics & storage, fodder produc-tion farms, supply of feed in the form of con-centrates and grain, credit and insurance and distribution and marketing are promising allied opportunities for investment and employment generation in the areas of dairy farming.

In India, women's involvement in livestock management is a longstanding tradition and dairy farming has been an integral part of homestead farming system.

Although much of the work related to livestock farming is carried out by women. Some important components like cleaning of claves, keeping of animals in shed, cleaning of shed, manure collection and dung cake making, regular milking of animals are done mainly by women in an appreciable manner. Selling out lets like animal fodder, dairy product processing industries, Packaging, establishment of bio gas plants and bio waste management units are new opportunities for employment generation as well as achieving rural self-reliance in the country in future.

The number of women entrepreneurs has grown over a period of time, especially in the 1990s. Women entrepreneurs need to be called for their increased utilization of modern technology, increased investments, finding a niche in the export market, creating a sizable employment for others and setting the trend for other women entrepreneurs in the organized sector. While women entrepreneurs have demonstrated their potential, the fact remains that they are capable of contributing much more than what they already are. Women's entrepreneurship needs to be studied separately for two main reasons. The first reason is that women's entrepreneurship has been recognized during the last decade as an important untapped source of economic growth. Women entrepreneurs create new jobs for themselves and others and also by being different. They also provide the society with different solutions to management, organization and business problems as well as to the exploitation of entrepreneurial opportunities. The second reason is that the topic of women in entrepreneurship has been largely neglected in society.

Problems of Women Entrepreneurs

Women entrepreneurs encounter the following general problems of entrepreneurs and problems specific to women entrepreneurs.

- **Problem of Finance:** Finance is regarded as "life-blood" for any enterprise, be it big or small. However, women entrepreneurs suffer from shortage of finance on two counts. Generally women do not have property on their names to use them as collateral for obtaining funds from external sources. Thus, their access to the external sources of funds is limited.
- **Scarcity of Raw Material:** The high price of raw material, on the one hand and getting raw material at the minimum of discount.
- **Stiff Competition:** Women entrepreneurs have to face a stiff competition for marketing their products with both organized sector and their male counterparts. Such a competition ultimately results in the liquidation of Women enterprises.
- **Limited Mobility:** Unlike men, women mobility in India is highly limited due to various reasons. It is mainly a woman's duty to look after the children and other members of the family. In case of married women, she has to strike a fine balance between her business and family. Support and approval of husbands seem necessary condition for women's entry into business. Accordingly, the educational level and family background of husbands positively influence women's entry into business activities.
- **Low Risk-Bearing Ability:** Women in India lead a protected life. They are less educated and economically not self-dependent. All these reduce their ability to bear risk involved in running an enterprise. Risk-bearing is an essential requisite of a successful entrepreneur.

Conclusion

Livestock management in dairy farming is usually carried out by women but the areas in which they need training the most are not given due consideration while designing training programmes. There is an urgent need to develop technologies which will help to carry out the activities with ease since they are relatively unpleasing, back breaking, monotonous and involve drudgery, physical exertion which ultimately affects their physical and psychological well being. Farm women have to be motivated to acquire more scientific knowledge for increasing the livestock production through various extension techniques.

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Achieving Extra Profitability in Traditional Farming

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Introduction

Farming has always been the backbone of our Country and a vital part of our food system. Despite modernization Traditional farming is still practiced by most of the Indian Framers. Realistically faming is a full day job, needs hard work, dedication, decision making unpredictable weather & market uncertainty. But to achieve extra profitability farmers need not have to drastically alter their faming style or to obtain pricey equipment, but innovative approaches, efficient practices, utilizing organic methods, quality food, following market trend, integrated farming, efficient marketing, etc., can increase their income. Proper utilization of resources and preserving traditions skill leads to not only benefits farmer but also contributes to environmental conservation and food security. Small & thoughtful changes in traditional farming can make a big impact to income.

Here are some ways to increase farm income with examples and actual benefits

1. Crop Planning

Most of the farmers did not change their cropping pattern because it is what they know; shifting of cropping pattern according to consumer demand is all they need to earn an extra.

What You Can Do

- Research which vegetables, herbs or grains are in demand locally or online.
- Try intercropping or multi-cropping-growing more than one crop on the same land to reduce risk and increase yield.
- Use crop rotation to maintain the soil's fertility and minimize pests.

Example

By adding a short-duration crop such as radish, spinach, or fenugreek between the wheat and rice cycles also earn an extra 10-25K/ acre based on market and crop choice.

2. Maximuml and Utilization

Thin strips along margins, bunds, and irrigation channelsare useful too.

What You Can Do

- Grow marigold, turmeric, or lemongrass along bunds.
- Plant coriander or spinach beneath trees or shaded corners.
- Employ trellises (vertical support) to cultivate climbers such as beans or gourds in vacant patches.

Example

Marigolds not only fetch good prices up to 3-15K per season in local markets but guarding your primary crops from nematodes and some pest insects,

3. Sell Smarter

Little effort in sorting, grading & packaging can fetch higher returns. Even including middle men for selling of produce often result in lower prices. Small adjustments can boost up the profits up to 30-50% per Kg.

What You Can Do

• Pack vegetables in clean packets and sell them directly to consumers, retail stores, or local stalls.

• Sell "kitchen packs" of mixed vegetables to your neighborhood homes or offices.

• Attempt a roadside stall or weekend market stall.

Example

Rather than selling tomatoes at ₹ 6/kg in bulk, you can sell neatly packed 1 kg bags for ₹ 10 – ₹ 12/kg to local shops.

4. Go Natural

Natural farming inputs are lower-cost, safer, and enhance long-term yields whereas & pesticide are costly & harmful for soil & health

What You Can Do

• Prepare jeevamrut, panchagavya or neem-based insect repellents at home.

• Employ vermicompost or cow dung manure in place of chemical fertilizers.

• Implement mulching to conserve soil moisture and suppress weeds.

Example

A farmer applying jeevamrut on one acre of tomato crop can reduce input costs by 40% and enhance yields by enhancing soil microbes.Natural inputs can save ₹ 5,000- ₹ 10,000 per acre per season.

5. Value Addition

Processing produce even to a small degree can increase its value manifold.

What You Can Do

• Dry chillies, ginger, or turmeric and grind them.

• Process sugarcane to produce jaggery instead of selling the cane.

• Pack pickles, dried herbs, or jam and sell it at local events or online.

Example

Fresh turmeric retails at ₹ 20- ₹ 25/kg, but it can be sold for ₹ 150 - ₹ 200/kg if dried and powdered and packed well, 3x–5x profit on the same produce with easy processing.

6. Animal + Crop Combo

Keeping animals on farm can provide regular and consistent income along with seasonal crops.

What You Can Do

• Maintain 2-5 goats or a few poultry birds that need hardly any additional space.

• Utilize cow dung and urine for compost or jeevamrut.

• Sell eggs, milk or manure locally.

Example

A 1-cow farmer can earn from milk, cow dung for compost, and even sell gobar-based natural fertilizers to other farmers or gardeners.

Profit Potential

Goat farming can generate ₹ 50,000– ₹ 1,00,000 annually from a few animals. Likewise, 10 hens can earn ₹ 3,000–₹ 5,000/ month from egg sales.

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Impact of Global Greenhouse Gas Emissions from Agriculture and its Resilience Methods: A Review

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Introduction

An essential source of income for people is agriculture, especially in an agrarian nation like India, where 58% of rural households rely on it for their sustenance and over half of the population who work works in this industry. (Eliazer Nelson *et al*., 2019; Chand 2022). The introduction of the Green Revolution in the 1960s and the White Revolution in the 1970s transformed Indian agriculture from a small local market to a global market, benefiting almost all consumers around the world, especially the poor. Particularly for all developing nations, agricultural productivity has grown at a remarkable rate, with increases of 208% and 109% for rice and wheat, respectively. (Pingali, 2012). India was the first country among the developing countries in Southeast Asia to experience the positive impact of the Green Revolution with an increase in yield in food grain along with China and other regions of Asia. The use of high-yielding varieties led to an increase in average yield from 1600 to 3030 kg/ha. Mean while, the usage of global fertilizer increased from 32 to 106 Mt (Megaton or million ton; 1 Mt = 1012g)/year (+331%) and the development of agricultural infrastructure like irrigation, roads, and price incentives encouraged wheat and rice production during the 1970s and 1980s. Tailor and Graph 2021). In addition, it also improved animal and plant domestication, crop rotation and breeding techniques.

Greenhouse gases (GHGs) are the gases in the atmosphere that raise the surface temperature of planets such as the Earth. Unlike other gases, greenhouse gases absorb the wavelengths of radiation that a planet emits, resulting in the greenhouse effect. The Earth is warmed by sunlight, causing its surface to radiate heat, which is then mostly absorbed by greenhouse gases. Without greenhouse gases in the atmosphere, the average temperature of Earth's surface would be about -18°C (0°F), (Jump and Qiancheng Ma, 1998) rather than the present average of 15°C (59°F). A substantial enhancement in agricultural production was brought about by the excessive use of nitrogen (N) fertilizers; however, modern farming techniques are unsustainable and release a lot of greenhouse gases, in part because of improper irrigation, ineffective crop and residue management, etc. Agriculture emissions from both direct and indirect related activities account for about 30% of total global anthropogenic GHG emissions. It further contributes to 60% of global nitrous oxide (N_2O) and 50% of methane (CH_4). The application of N fertilizer is primarily responsible for N_2O emissions, whereas rice cultivation and cattle enteric fermentation are the primary sources of CH_4 emissions, which account for the majority of worldwide agricultural GHG emissions. Also, the biomass burning of forest and crop residues contributes to both CH_4 and N_2O emissions. Nitrogen addition to croplands has increased by 30% (~ 7.3 Tg N/year; Tg or teragrams = 1012 g) over the last four decades as a result of growing economies such as Brazil, China and India. With an estimated 9 billion people by 2050, food production needs to be increased by 70% to meet the global food demand. This also implies that the agricu-lture and industrial sectors will largely drive future GHG emissions. Therefore, it is imperative to deploy the best management practices (BMP) and smart farming technol-ogies that will not only meet the food requirement but also mitigate further GHG emissions.

Sources of GHG emissions in agriculture

Livestock

The livestock industry uses one-third of the freshwater and cropland for feed, making up almost 30% of the world's land-use system. The sector provides a source of income and economic benefits for more than 1.3 billion people and contributes about half of the worlds agricultural GDP. India has the largest number of agricultural livestock in the world. Though the country covers only 2.4% of the world's geographic area with 0.5% of pasture lands, it supports nearly 15% of global livestock (MoEFCC 2018). Livestock forms an integral part of the Indian agricultural and socioeconomic systems. It gives employment to 8% of India's total population by providing livelihood to 20.6 million people. For instance, in this system, cattle are not only a source of milk, but they also contribute to draught power, act as capital and insurance when the crop fails and also provide nutrient cycling. Livestock is vulnerable to climate change, but itself is a substantial contributor to GHG. In the 19th livestock census report, the number of livestock in India was 512 million, with cattle and buffaloes constituting more than 60% of the total livestock (Department of Animal Husbandry Dairying and Fisheries 2012). The livestock population reached 535.78 million in the 20th livestock census report (Livestock Census 2019). Owing to the gradual growth in the number of livestock, there is a steady increase in GHG emissions particularly CH_4 and N_2O respe-ctively. However, currently, they also have a high potential for cost-effective reduction in the agricultural sector by improving their productivity, the feeds and the proper management of livestock manure.

CH_4 emissions from enteric fermentation

The two main mechanisms that contribute to livestock's CH_4 emissions are "enteric fermentation" and "manure management". In many nations, they are the main cause of agricultural emissions. Ruminants digest cellulose, the basic building block of plant cell walls, in a process known as enteric fermentation. Simple and complex carboh-ydrates, such as cellulose, are fermented by microorganisms to produce volatile fatty acids (VFAs), which serve as an energy source (about 70% of calorific requirements of ruminants come from VFA) (Bergman 1990). Along with VFA, hydrogen (H_2) is also produced which is converted to CH_4 by methanogenic bacteria. Around ninety per cent of all CH_4 emissions come from this process. The percentage rise of enteric methane emissions (EME) over 1961-2010 was larger for Indian livestock (70.6%) than for world livestock (54.3%). Indian livestock contributed 11.8 Tg/year (11%) out of the total global 87–94 Tg/year livestock CH4 emissions (Chhabra *et al.*, 2013; Achparaki *et al.*, 2012). The maximum CH_4 emissions in state-wise come from Uttar Pradesh (U.P), Madhya Pradesh and Andhra Pradesh with 15%, 9.41% and 9.20%, respectively, of the total livestock emissions in India. Goats and sheep emit 105 kg CO_2e CH_4/ head/year, cattle emits 672 kg CO_2e CH_4/ head/year and buffalo emits the highest among them with 1155 kg CO_2e CH_4/ head/year. Nevertheless, due to high populations of cattle, they contributed the highest CH_4 emissions (> 50%). Although the emission coefficient is lower for indigenous livestock, they have higher CH_4 emissions due to their dominance compared to exotic animals (Chhabra *et al.*, 2013). CH_4 emissions are projected to increase by 386% from 14.08 Tg in 2007 to 68.49 Tg in 2032.

The production of CH_4 is not only a threat to climate change but also a loss of dietary gross energy (57%) as a kg of CH_4 contains 55.22 MJ (megajoule; 1 MJ = 106 Joule) of energy. The amount of feed intake and digestibility of feeds are related to CH_4 production. Also, livestock characteristics such as age, weight, species and health affect the amount of energy required. Adult dairy cattle and buffalo produce more CH_4 by enteric fermentation as compared to young non-dairy cattle and buffalo below a year old. Increased CH_4 generation results from rising energy demands and feed intake. For example, Asian cow species (Bos indicus) require 10% less energy than European and North American cattle species (Bos taurus). (Council 1996). Increased CH_4 generation results from rising energy demands and feed intake. For example, Asian cow species (Bos indicus) require 10% less energy than European and North American cattle species (Bos taurus) (Sirohi and Michaelowa 2007).

CH_4 and N_2O emissions from manure management

The primary sources of N_2O emissions and a small amount of CH_4 are livestock dung, which is made up of urine and excrement. India's annual CH_4 emissions from manure increased from 0.52 to 1.1 Mt between 1960 and 2010, growing by 1.57% annually. (Patra 2014). Poultry reported the highest increase rate for CH_4 emissions from manure, which was 4.28% greater than the global annual growth rate. Buffaloes (31.4%) and cattle (26.7%) were found to produce the highest N_2O among Indian

Livestock, with other species accounting for the remaining portion. During the nitrification and denitrification process, nitrifiers and denitrifier microorganisms are the main producers of N_2O. Almost 70% of the world's N_2O emissions come from these two microbiological activities. The process of nitrification involves the aerobic oxidation of ammonium (NH_4^+) to nitrate (NO_3^-), while denitrification takes place anaerobically when NO_3^- is reduced to CO_2. Manure's N_2O emissions are expected to rise from 15.3 Gg in 2010 to 21.4 Gg in 2050.

Methane production from rice

The main greenhouse gas produced by irrigated rice-growing techniques is methane (CH_4). Methane synthesis, oxidation and transport all contribute to the overall methane emissions from a paddy field. These in turn are affected by the physical, chemical and biological properties of the soil, quantity of organic residues, temperature, plant physiology and water regime. Methanogenesis, methane production, is a microbial process strictly limited to anaerobic condition. In the brief period subsequent to flooding, paddy soil becomes anoxic because oxygen can flow in water, but the rate of diffusion is 10,000 times slower than in air (Bodelier 2003). Considering the assertion that not all rice is farmed in floods, 90% of rice land is at least temporarily flooded worldwide. Ammonium inhibits its oxidation at the soil/water surface layer, where it is anticipated to oxidise more readily than CH_4 Since nitrate, a byproduct of ammonium nitrifica-tion, can hinder methanogenesis, it is not reasonable to extrapolate that ammonium-fertilised fields will produce higher CH_4 emissions.

GHG emissions from synthetic fertilizers use

Nitrogen fertilizers

The main production method for N-fertilizers is through the Haber- Bosch process (Haber and Le Rossignol (1916). It is an energy-intensive procedure that converts nitrogen taken from the air and hydrogen, typically from the CH_4 in natural gas, into ammonia. According to the International Fertilisers Industry Association, this ammonia can then be utilised to create N-fertilisers, particularly urea ($CO(NH_2)_2$) and ammonium nitrate (NH_4NO_3), which account for over 75% of the world's usage of straight N-fertiliser (IFA, 2019).

Phosphorus fertilizers

The second important macronutrient is phosphorus (P), which is typically made into fertilisers by chemically treating phosphate rocks that are mined. These rocks undergo sulphuric acid (H_2SO_4) treatment to produce phosphoric acid (H_2PO_4), which is then utilised in the production of several popular P fertilisers, including diammonium phosphate ($(NH_4)_2HPO_4$), monocalcium phosphate ($Ca(H_2PO_4)_2$) and monoammonium phosphate ($NH_4H_2PO_4$). Although single superphosphate (45.6% straight, 8.2% total) and triple superphosphate (31.7% straight, 5.7% total) make up the majority of the straight (single nutrient) P-fertiliser market, ammonium phosphates are by far the most widely used P-fertiliser, accounting for 48.7% of global P-fertiliser consumption (IFA, 2019). While emissions for super phosphates are much smaller, they nevertheless exhibit a large variance, whereas EFs for ammonium phosphates range from 1.3 to 8.9 kg CO_2-eq./kg of P_2O_5. Because ammonia is required for the process, ammonium phosphates are generally predicted to have a higher emission factor.

Potassium fertilizers

Typically, crops receive potassium (K), the last of the main macronutrients, in the form of potash, which includes a range of K-bearing salts, such as potassium chloride (Kcl), potassium sulphate (K_2SO_4) and potassium nitrate (KNO_3) (Fixen and Johnston, 2012). Mining is the most popular technique of producing potash, much like it is with phosphorus. According to a recent life cycle assessment of Kcl production, the production of potassium chloride led to the emission of 0.19 kg CO_2-eq./kg of K_2O or 0.11 kg CO_2-eq./kg of KCl, with a 95% confidence interval between 0.14 and 0.25 kg CO_2-eq./kg of K_2O. Of these emissions, energy generation accounted for 72.61% of the total, while on-site emissions of CO_2 and N_2O during the manufacturing process accounted for 25.70%.

Resilience methods to reduce GHG emissions in agriculture

Farm-level resilience methods

Agro forestry: In agricultural operations, agroforestry techniques like woodlots, afforestation, shelterbelts, silvipasture and forested riparian buffers can lower and eliminate CO_2 emissions from the atmosphere. Any local or international emissions restriction will have a less overall economic impact if cost-effective mitigation and removal possibilities are available. By lowering emissions, the agriculture sector may increase production efficiency, preserve water and soil resources and support global warming mitigation initiatives (Kort. J & R. Turnock, 1998).

Conservation Agriculture: Shifting to CA for agricultural production systems may significantly reduce GHGE from agriculture. As the soil builds up in these conditions, carbon can even be stored as organic matter. This not only offsets the remaining emissions but makes the soil a net carbon sink. The SOC accumulation starts in the first year of conversion to CA and stores at least 500 kg CO_2e ha-1. If this cropping system is maintained in perpetuity, emissions will continue to decrease due to reduced fertilizer and pesticide application rates, increasing the annual net sequestration up to 1350 kg CO_2e ha-1. In addition to reducing greenh-ouse gases, CA reduces erosion by 98%. This can stop the increasing soil degradation that causes enormous GHGE.

Crop rotation and intercropping: The experiments with different crop rotation treatments in a rice field showed that crop rotation with corn (RC) and sweet sorghum (RS) in the dry season, can significantly reduce annual GHG emissions (combined CH_4 and N_2O in CO_2 equivalent) by 68-78%, as compared to double rice cultivation (RR). In the case of the single rain-fed rice field, despite the low CH_4 emission, a lower annual cumulative rice yield was also observed. N_2O emissions exhibited a pattern contrary to CH_4 emissions. The rotation crops (RC and RS) increased N_2O emissions by five to nine times over that of the double rice cultivation (RR). However, the contribution of N_2O emissions from RC and RS to the CO_2 equivalent emissions was small and accounted for 27-39% of the net CO_2 equivalent (CH_2 + N_2O) emissions.

Landscape-level resilience methods

Sustainable land-use planning: Through the promotion of approaches that reduce land-based emissions and improve carbon sequestration, sustainable land-use planning may substantially reduce greenhouse gas (GHG) emissions. This involves ceasing deforestation, using sustainable farming methods and restoring ecosystems that have been destroyed. We can increase carbon storage in soils and plants while minimizing emissions from practices like fertilizer usage and animal production by managing land correctly (Liang Wang, 2024).

Ecosystem-based adaptation: Ecosystem-based adaptation (EbA) encourages the preservation, restoration and sustainable management of carbon-sink ecosystems, which can help lower greenhouse gas (GHG) emissions. Forests, wetlands and coastal regions are examples of ecosystems that can successfully mitigate climate change by absorbing and storing atmospheric carbon dioxide. Ecological, social and economic advantages are provided by EbA, which also supplements or replaces simply technological infrastructure initiatives

Climate-smart agriculture: The goal of climate-smart agriculture (CSA) is to increase production and climate change resilience while lowering greenhouse gas (GHG) emissions from agricultural activities. In order to do this, CSA employs techniques that help create a more sustain-able and climate-resilient agricultural system, including crop diversification, optimal fertiliser use and effective water usage.

Policy and Institutional resilience methods

Climate polices and incentives: Incentives and policies related to climate change are essential for eliminating greenhouse gas emissions. These policies fall into two categories: market-based strategies like cap-and-trade programmes and carbon pricing and regulatory strategies like performance requirements and low-carbon technology subsidies. Emissions reductions can also be promoted by incentives such as lower taxes for electric vehicles or investments in renewable energy (Center for Sustainable Systems).

Agricultural research and development: Globally, focused environmental regulations are more successful in reducing greenhouse gas emissions from land-use change than increased research and development investments aimed at boosting productivity growth. However, accelerated productivity growth reduces emissions intensity of agricultural production and reduces the cost of the environmental policy. Moreover, higher levels of productivity permanently lower agricultural GHG emissions and generally improve global food security. Policies that restrict agricultural factor inputs in order to reduce local environmental costs may increase global agricultural GHG emissions and worsen food insecurity. These consequences could be avoided by increasing R&D spending to accelerate agricultural productivity growth that is either factor neutral or biased toward saving production factors associated with negative environmental externalities.

Conclusion

In contrast to other gases, greenhouse gases absorb the various wavelengths of light. The cattle enterprises consume one-third of freshwater and farmland for feed, accounting for over 30% of the world's land use system. Livestock CH_4 emissions are mostly caused by "enteric fermentation" and "manure management". In many countries, they constitute the leading source of agricultural emissions. Methane (CH_4) is the primary greenhouse gas generated by irrigated rice cultivation methods. The total amount of methane released from a paddy field is influenced by methane production, oxidation and transport. Likewise, the fertilizers also supply gases as N-fertilizers is through the energy-intensive procedure that converts nitrogen taken from the air and hydrogen, typically from the CH_4 in natural gas, into ammonia, phosphorus (P), which is typically made into fertilizers by chemically treating phosphate rocks that are mined and potassium (K) in the form of potash, which includes a range of K-bearing salts. The remedy measures like agroforestry, woodlots, afforestation, shelterbelts, silvipasture can lower and eliminate CO_2 emissions from the atmosphere.

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Landscape Architecture 2.0- Emerging Trends, Designs, Challenges and Opportunities

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Introduction

Embracing Tradition and Modernity in Indian Landscape Design India's deep-rooted cultural heritage in gardening and horticulture has long maintained a profound connection with nature. From the intricate Mughal gardens to traditional Indian courtyards, landscape design in India has historically blended aesthetics with functionality. However, as urbanization and sustainability become increasingly crucial, contemporary landscape architecture is evolving to address challenges such as climate change, population density and eco-conscious living. This article delves into the future of landscape design in India and the key trends shaping its transformation.

The Rise of Sustainable Landscape Design in India

Sustainability is at the core of modern landscape design in India. With a growing emphasis on environmental conservation, landscape architects are integrating eco-friendly practices that enhance long-term ecological health.

Key Sustainable Practices

- **Native Plant Integration:** Incorporating indigenous plant species enhances resilience to local climatic conditions, minimizes water usage and promotes biodiversity.
- **Rainwater Harvesting Systems:** Many landscape projects now include mechanisms for rainwater collection, reducing dependency on municipal water supplies and enhancing self-sufficiency.
- **Solar-Powered Lighting:** The adoption of solar energy for garden and park lighting significantly reduces energy consumption and carbon footprints.

These sustainable methodologies are expected to dominate upcoming landscape initiatives, particularly in urban settings striving for greener and healthier environments.

Urban Green Spaces: Bringing Nature into Indian Cities

With rapid urban expansion, green spaces are diminishing. To counteract this trend, landscape architects are incorporating innovative solutions to integrate greenery into urban areas.

Innovations in Urban Green Spaces

- **Rooftop Gardens:** These gardens optimize limited city space, providing aesthetic appeal while aiding in temperature regulation and reducing the urban heat island effect.
- **Vertical Gardens:** Green walls enhance air purification, contribute to cooling and promote biodiversity, even in compact urban settings.
- **Urban Parks:** Cities like Delhi, Mumbai and Bangalore are investing in expansive parks to mitigate pollution and provide recreational areas for communities.

By prioritizing green infrastructure, Indian urban centers are moving toward a more livable and sustainable future.

Preserving Biodiversity through Landscape Design

India's vast biodiversity, spanning from the Himalayas to tropical rainforests, is increasingly under threat due to rapid development. Modern landscape design is now focused on conservation efforts that both beautify spaces and support wildlife.

Conservation-Oriented Designs

- **Butterfly Gardens:** Landscapes featuring nectar-rich flowers encourage pollination and enhance biodiversity.
- **Bird Habitats:** Designed to attract and sustain bird populations, these landscapes serve as urban sanctuaries for native avian species.
- **Conservation Parks:** These spaces protect endangered flora and fauna while educating the public on the importance of conservation.

By integrating biodiversity-friendly elements, landscape architects are ensuring ecological balance and environmental sustainability.

Integrating Smart Technology in Indian Landscape Design

Technology is revolutionizing modern landscaping, making garden management more efficient and resource-conscious.

Smart Landscape Solutions

- **Automated Irrigation Systems:** These systems analyze soil moisture and weather data to optimize water distribution, crucial for regions facing water shortages.
- **Remote Garden Maintenance:** Mobile applications now enable users to schedule watering, fertilization and plant health monitoring remotely.
- **Solar Energy for Outdoor Lighting:** Solar-powered lighting reduces energy costs and environmental impact in large-scale landscape projects.

The incorporation of smart solutions is enhancing sustainability while reducing manual upkeep in landscape design.

Wellness Gardens: Enhancing Health and Well-Being

As awareness of nature's impact on mental and physical health grows, wellness gardens are becoming an integral part of landscape design in India. These gardens are designed to provide tranquil environments that foster relaxation and mindfulness.

Features of Wellness Gardens

- **Meditation Spaces:** Secluded areas near water features or within tree canopies offer ideal settings for mindfulness and reflection.
- **Aromatherapy Gardens:** Planting fragrant species such as lavender, jasmine and rosemary creates a soothing sensory experience.
- **Yoga Platforms:** Open-air spaces designed for yoga and tai chi sessions promote overall well-being.

The rise of wellness-oriented landscapes signifies a shift towards holistic urban planning.

Drought-Resistant Landscaping for India's Climate

India's diverse climatic conditions necessitate innovative water-efficient landscaping strategies, particularly in drought-prone regions.

Water-Saving Landscaping Techniques

- **Xeriscaping:** This method employs drought-tolerant plants that require minimal water, reducing maintenance and conservation costs.
- **Rock and Gravel Gardens:** These landscapes serve as aesthetically pleasing alternatives to traditional lawns in arid regions.
- **Drip Irrigation Systems:** Direct water application at plant roots reduces evaporation and wastage.

By adopting drought-resistant techniques, landscape architects are ensuring sustainable greenery across varied climatic zones.

Conclusion

The future of landscape design in India is being shaped by the harmonious integration of tradition and innovation. By prioritizing sustainability, biodiversity conservation, smart technology and wellness-focused landscapes, Indian cities are evolving into greener, more resilient environments. As landscape architects continue to embrace eco-friendly and technological advancements, India's landscapes will not only flourish aesthetically but also contribute significan-tly to environmental and social well-being.

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Senna: An Excellent Medicinal Crop

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Introduction

Now-a-days, ancient natural therapy methods for curing human body's aliment is gaining popularity because of the high side effects, drug reactions, cost constraints of the modern allopathetic treatments. The utilization of plant based medicines is well documented in our Vedic literature viz., *Ayurveda*. We have a long list of medicinal plants and they have been utilized since many centuries. Manufacturing based survey of modern allopathic medicine reveals that they use nearly 25% of the medicinal plant's extract directly or indirectly in their medicines (Deshpande and Bhalsing, 2013). Among all the medicinal plants, senna (B.N.: *Cassis angustifolia* Vahl, Family: leguminaceae, 2n= 28 & centre of origin: Sudan) is having its own value because of its valuable sennosides content which is present in the pod shell and leaves of the plant. In ayurvedic literature, senna has been described as 'Swarnapatri' in sanskrit and considered as pitta shodhaka *i.e.*, effective in balancing the 'pitta' and 'vataanulomaka' *i.e.*, effective in removing vata from alimentary cannal. Because of these properties senna is considered as wonderful laxative.

Senna is also considered as FDA (Food & Drug Administration) approved non-prescription laxative. Due to its excellent colon cleaning activity it is recommended to clear the bowel before diagonostic test such as colonoscopy. The utility of senna is not restricted only to the ayurvedic treatment rather it has also occupied its place in the other treatment methods viz., in homeopathy, unani etc. Today, senna formulations are available with several names under various treatment methods as represented in the table no. 1.

Table: 1. List of the senna formulation under various treatment methods

Senna formulation	Type of treatment system
Punch Sakaarachurna	Ayurveda
Shtshakaarchurna	Ayurveda
Ayulax	Ayurveda
Sarivadyasava	Ayurveda
Yashtyaadichurna	Ayurveda
Raktansoo syrup	Ayurveda
Safoof-e-Mulaiyia	Unani
Majoon-e-Senaai	Unani
MajoonMusaffi-i-Khoon	Unani

This herb is cultivated in warm and dry regions of India on nutrient deficit soil as rainfed crop. Senna is mostly cultivated as annual herb in Tamil Nadu, Andhra Pradesh and Karnataka but in some parts of our country it is cultivated as perennial herb like in Gujarat (Kutch) and Rajasthan (Jodhpur). The major growing belt of senna in India is Tamil Nadu, Andhra Pradesh and Karnataka. It is an upright, annual/ perennial shrub which attains the height range from 100-200m. The length of racemose inflorescence is about 30-45cm having yellow petals. The length of pod is 5cm which contains 5-7 seeds.

Plate 1: Parts of the senna plant

Seed of Senna

Dried pod of Senna

Dried leaves of Senna

Dried stem of senna

Cultivation practices of senna

Soil and climate

Senna is considered as an easy crop for cultivation because it can be grown very well on variety of soil from sandy, loam, gravel to alluvial with proper drainage property. It cangrow well under neutral pH (7 to 8) of soil. Senna can perform well under mild tropical climate and also in mild winter but it very sensitive towards frost condition. The performance of this herb is quite appreciable when it is cultivated in low soil moisture condition, little drought condition as well as in salt effected soil. Senna growing areas reflects that farmers are mostly cultivating this crop in rainfed condition but few are practicing it under irrigated condition also.

Seed sowing and establishment

Senna is commercially propagated through seed. Soil preparation is done before seed sowing that include ploughing, harrowing and leveling of soil. In Gujarat and South India, it is sown in the month of July to November whereas in the north indian condition it is cultivated in the month of February to March. Line sowing is done by broadcasting/drilling by maintaining 30cm row to row distance. Under rainfed condition, the seed rate is 25 kg/ha whereas under irrigated condition it is 15 kg/ha. Senna seeds takes one week to germinate after sowing but sometimes scarification methods is to be done to increase its moisture absorption ability because of its hard seed coat. The seed colour is also an important constraint in the seed germination ability. Yellow colored seed is having more capacity of germination than green colored seed. After germination thinning of plants is done and 10-15 cm plant to plant distance is maintained.

Weeding and Intercultural practices

It is very much essential to keep the crop free from weed so 3-4 times weeding and 2-3 times hoeing is to be practiced. Under north Indian condition, it takes 45 days to initiate flowering after sowing. First flush of flowering is wasted to allow more growth of lateral branches. Under rainfed condition, multi-cut senna is taken whereas in the soil having residual moisture, this medicinal herb is taken as a second crop after sorghum, coriander or cotton.

Irrigation

Heavy rainfall for longer duration as well as water logging condition are unfavourable for senna as it is taken as rainfed crop. But for proper germination and suitable growth of the plant, slight irrigation/dizzling condition is also required. The amount of irrigation depends upon the climatic condition where it has to be cultivated. When it is taken under semi-irrigated condition of

North India, proper moisture is required for the root zone area when sun is high in the month of March and April. Regular rainfall during the growth period detoriate the quality of leaves and also reduce the sennoside concertation in the pods and leaves as well. It can also be successfully grown as intercrop withothers where light becomes limiting factor. Under normal growing condition senna should be irrigated at 4-5 weeks' interval.

Manuring

Even though senna belongs to the leguminaceae family, it is incapable to fix atmospheric nitrogen through its roots because it does not involve nodule format-ion. Recommended fertilizer (N:P:K) dose in kg/ha required for senna is 100-200:50:50. The nitrogen should be applied in 2-3 splits. Foliar application of micronutr-ients impro-ves the sennosides contents and yield. Along with the fertilizers and micronutri-ents, organic manure (FYM @10 t/ha) should also be applied to maintain the quality of this herb and soil at the time of land preparation.

Plant protection

During dry and warm condition, it is not affected by diseases and pest. But there is incidence of disease and pest when this crop receives moisture condition for long duration. Attack of white fly (*Catopsilla pyranthae*) occurs during high temperature and moisture condition. The two most serious diseases of senna are leaf blight caused by *Phyllostica* spps. And leaf spot caused by *Alternaria alterneta*. When cloudy and moist condition occurs there is the presence of small spots on the leaves and on severs infection the leaves become yellow and fall down. In the advance stage, the pods also get affected. Use of carbandazim or dithiocarbant @ 0.03% spray over crop at fortnight intervals three times is beneficial in controlling these problems. Crop is also affected by damping off at the seedling stage, hence seed treatment with fungicide mancozeb is done before sowing, keeping in mind that the used concentration of fungicide would not affect the sennoside content of pod seeds and leaves.

Crop rotation

It gets fit in crop rotation when it is grown as *kharif* crop in the commercial area of cultivation. In the south Indian states, it is grown after paddy and in northern and western India, it is grown after mustard and coriander respectively.

Harvesting

Various parts of the senna like, leaves, pods and whole plant is harvested (Plate 1.). The practice of harvesting parts of senna varied from region to region. Harvesting of seena leaves should be done after three months of sowing when it bears green blusish leaves in bulk. In each harvesting of leaves, only 50 % of the leaves should be harvested for creating the opportunity to have fully developed leaves for the consecutive harvesting. The whole plant of seena should be harvested after three months of sowing leaving the 5-10 cm height from the ground level, this practice is followed in Northern and Western India whereas leaves and pods are harvested in South India specially in Tamil Nadu belt. When there is whole plant harvesting aflatoxin contamination is also less. Senna leaves and pods should be harvested at the interval of one month. Three to four harvesting should be done and sometimes at the end of harvesting whole plant is taken out. Senna is grown as annual crop but can be treated as perennial and harvesting should be continued for the 2-3 consecutive years.

For the seed production, pods should be harvested when they turn light brown in colour. The seeds obtained from properly matured pods are having high germination percent. The mature collected pods are dried to extract seeds from them. Under standard cultivation practices, the average pod yield is 700 kg/ha and seed yield is about 300-400 kg per ha. The average dry leaves yield under rainfed condition is 600-700 kg/ha whereas under irrigated condition it is about 1500-2000 kg/ha. The sennoside concentration is 2.5% in the leaves and 3.6% in the pods.

Drying and grading

The quality of products obtained from seena is dependent upon the it's proper drying and grading. Just after harvesting, the senna leaves are dried in open sun for 6-10 hrs to reduce the moisture content. Thereafter, the leaves are taken under shade drying for 3-6 days to reduce the moisture content up to 8-10 percent. It is recommended to dry the senna leaves at 45 degree celsius for 2.5 hrs to have higher accumulation of sennoside in the leaves than sun drying. While performing the step of drying there should be proper turning of leaves for uniform drying. The colour of the final dried leaves should be light green to greenish yellow as these fetch good price in the market. Also, larger leaves and bold pods are more demanding among buyers.

Grading

After proper drying of the senna leaves, they are manually or mechanically winnowed to remove dust and small stones. After that they are passed through sieve for grading purpose. Prime 1 to prime 5 are the grade of senna and from which prime 1, 2 and 3 is exported to international market whereas prime 4 and 5 are retain for selling in Indian market. After grading, value added products like flavoured senna leaf, senna tea, senna tablets etc., can be made.

Medicinal Uses

Arabians were the first to discover the medicinal properties of senn since 900 A.D. The purgative properties of senna are due to its two important glycosides viz., Sennoside A and Sennoside B (Sterioisomers of dihydrodianthraone glucosides). But senna leaves also contain sennoside C and D (aloeemodin dianthraone diglucosides). However, the medicinal content of senna is mainly due to its sennoside A and B which contribute towards the 80 % of its medicinal property. Senna laxative preparations are used world wide and it is more popular in the countries like United Sates, India, Britain and other parts of the world. From the research it has been evident that the more concentration of sennoside is found in the pod shells and leaves of seena. But not only the vegetative parts (leaves, pods, bark, petiole, leaflets etc.) are having sennoside content but reproductive parts (like anther, filament, petlas, calyx, pedicle, anther, filament etc.,) also contain it. It has been observed that the sinnoside content in the senna leaves are increased after drying but in case of pods, sinnoside concentation are more in early harvested pods than late one. A part from the main constituent sennoside, seena plant

Improved varieties of senna

Variety	Source of availability
ALFT-2	AICRP on Medicinal and Aromatic Plants, Anand Agricultural University, Anand, Gujarat
Tinnevelly Senna	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu
Sona	Central Institute for Medicinal and Aromatic Plants, Lucknow, Uttar Pradesh
KKM-Se1	Agriculture College and Research Institute, Killikulam, Tamil Nadu
Gujarat Anand Senna -1	Anand Agricultural University, Ananad, Gujarat

also have appreciable amount of macro and micro elements viz., calcium, potassium, magnesium, sodium, iron and zinc in it.

Apart from its purgative properties senna is utilized for treating weaker appetite, heptomegaly, splenomegaly, jaundice, diabeties, rheumatoid arthritis, goutetc. It also has antibacterial, antifungal, antioxidant activity and is used in the purification of blood. The paste of seena leaves mixed with vinegar is utilized for treating face pimples. It is also usefulin treating ring worm. Inaddition to the health benefits, senna has also been used as safe pesticide.

Precaution

The herb is not to be administered to the patients with hypersensitivity to senna or senna preparations. Not to be used in cases of intestinal obstructions and stenosis, atony, appendicitis, inflammatory colon diseases (e.g., Crohn's Disease, ulcerative colitis); abdominal pain of unknown origin, severe dehydration state with water & electrolyte depletion. Senna is not recommended for use in children under 12 years of age.

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Insect Pest Management in Vegetables Using Biopesticides

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Introduction

Farming in this era is threatened by overexploitation of natural resources, indiscriminate pesticide use and the unpredictable impacts of climate change. In this context, biopesticides have emerged as a vital component of Integrated Pest Management (IPM), offering eco-friendly and sustainable alternatives to conventional chemical pesticides. These biological agents derived from natural organisms have proven effective in controlling a wide range of pests and diseases across diverse farming systems. Despite their potential, the adoption of biopesticides in India faces few challenges. While several countries like the EU and USA have already restricted or banned hazardous chemical pesticides, India is also gradually shifting towards safer pest control methods. The integration of biopesticides into crop protection strategies not only addresses issues like pesticide resistance and environmental degradation but also aligns with global trends in sustainable agriculture. Promoting their use requires a collaborative effort among government agencies, private enterprises and farming communities.

Biopesticides

Biopesticides or biological pesticides are derived from naturally occurring living organisms including plants, animals and microbes (fungi, bacteria, virus, nematodes, etc.) used as such or as their products or by-products that can control serious pest and diseases of plants by their non-toxic eco-friendly mechanism.

Biopesticides are described as mass-produced agents obtained from living organisms or a natural material manufactured and marketed for the control of plant pests, according to the Organization for Economic Co-operation and Development (OECD).

The target specific biopesticides gaining importance all over the world because as they offer an effective and ecologically sound solution to the pest problems. Biopesticides are broadly classified into four different categories based on the origin of the active substance or the living organism used in the control of target pest. Among the major biopesticides produced and used in India are T*richoderma*, *Bacillus thuringiensis,* nuclear polyhedrosis virus and neem-based pesticides (Rani *et al*., 2021).

Important pests of vegetables

Major pests observed in vegetables are Aphids, Thrips, Leaf eating caterpillars & Borers, Leaf miners, Fruit flies, Whiteflies and White grub.

Insect Pests

Aphids

Infested Hosts	Name of Species
Okra Potato Cucurbits	*Aphis gossypii* *Myzus persicae* *Myzus persicae*

Management of Aphids by Biopesticides

- Use *Metarhizium anisopliae* 5g per litre water
- *Beauvaria bassiana* 5g per litre water foliar spray.
- Use waste decomposer solution (30 ml for 10 litres of water) to repel aphids
- Use Neem oil 5ml in 1 litre water to reduce aphid population
- Release lacewings (1000), syrphids fly (1200-1500), lady beetles (1500-2000) per square feet.
- **Pyrethrin:** Extracted from chrysanthemum flowers, pyrethrin-based biopesticides are effective against a range of pests, including aphids and thrips.
- Adequate natural enemies can prevent aphids without any treatment but natural enemy population does not occur until aphid population increases.

Thrips

Infested Hosts	Name of Species
Tomato Onion Chilli	*Thrips tabaci* *Thrips tabaci* *Scirtothrips dorsalis*

Management of Thrips by Biopesticides

Name of Species	Parasitoid	Predators
Thrips tabaci	*Eulophidea*	*Oenopia kirby*
Scirotothrips dorsalis	*Trichogrammatidae*	Green lace wing bug
Rhiphiphora cruentatus	*Mymaridea*	Minute pirate bug
Scirotothrips dorsalis	*Trichogrammatidae*	*Euseius species (mite)*

- Beauvaria bassiana 5 grams per litre water
- M-pede (insecticidal soap) 30 ml per 3 litre water
- Azadiractin1000 ppm 5 to 10 ml per litre water
- Use horticulture oils (10 ml per litre water) and spray on buds and floral parts

Fruit fly

Infested Host	Name of Species
Cucumber	*Batrocera Cucumis*

Management of Fruit fly by Biopesticides

Name of Species	Parasitoid	Predators
Batrocera Cucumis	*Elasmus species*	*Oecophylla longinoda*

- Use bait application technique such as cuelure, trimed lure, methyl eugenol.
- Place *Metarhizum anisopilea* 3-5 grams per plant granules on soil.
- Neem oil @10000ppm.
- Inoculate neem cake into the soil to kill pupating larva.
- Install cucurbit fruit fly traps.
- Biopesticides viz. Ambush 1.8 EC (Abamectin) Tracer 45 SC (Spinosad) and Mycotal (L. *muscarium*).

Leaf Miner

Infested Hosts	Name of Species
Tomato All gourds	*Tuta absoluta* *Liriomyza trifoli*

Management of Leaf Miners by Biopesticides

Name of Species	Parasitoid	Predators
Tuta absoluta *Liriomyza trifoli*	*Pteromalidae species* *Mymaridae species*	Carabidae Dragon fly

- In warm weather leaf miners will be more active
- Spray Pongamia oil 5ml per litre water or neem oil immediately after detection
- Spraying of *Metarhizium* @ 5ml per litre of water.
- Spraying of tobacco decoction (1 kg of tobacco leaves + 10 l of cow urine).
- Spraying of *Bt* formulations (DIPEL, DELFIN, BIOVIT, HALT) @ 400g or 400 ml per acre.

White Fly

Infested Hosts	Name of Species
Tomato	*Bemisia tabaci*
Onion	*Bemisia tabaci*
Chilli	*Bemisia tabaci*

Management of White fly by Biopesticides

Name of Species	Parasitoid	Predators
Bemisia tabaci	*Encyrtidae species*	Lace wing bug

- During warm weather population become more abundant in vegetables
- Insecticidal soap 10ml per litre water will reduce population but not eliminate entire population.
- Watering can also reduce hot dry conditions that favour white flies
- Place sticky trap coated with castor oil 1-2 per sqm
- Use entomopathogenic fungi *Beauveria bassiana* and *Isaria fumosorosea* @ 5g per litre water
- Use insectivorous plants.
- Spraying of NSKE @ 5%.

White grub

Infested Hosts	Name of Species
Potato	*Holotrichia serrata*

Management

Drenching with Metarhizium @ 5ml per litre of water.

Leaf eating Caterpillars and Borers

Infested Hosts	Name of Species
Tomato fruit borer	*Helicoverpa armigera*
Okra fruit borer	*Earias vitelli*
Tomato leaf eating caterpillar	*Spodoptera litura*
Potato tobacco borer	*Spodoptera litura*
Pumpkin caterpillar	*Diaphania indica*
Potato tuber moth	*Pthorimae opercullela*

Management of Leaf eating caterpillars and borers by Biopesticides

Name of Species	Parasitoid	Predators
Helicoverpa armigera	*Trichogrammatidae*	Carabidae
Luicinoides orbonalis	*Trichogrammatidae*	Dragon fly
Earias vitelli	*Chilonus blackburni*	Reduviid bugs
Spodoptera litura	*Eurytoma*	Labiduridae
Pthorimae opercullela	*Braconid species*	Reduvid bugs

- Spray neem oil 1500 ppm 5ml/litre water.
- Pheromone Pherodine to attract male tomato leaf eating caterpillar and spodolure for spodoptera
- Releasing of egg parasitoid *Tricogramma-chilonis* at weekly interval @ 1.5 lakhs per ha or release of 2*nd* instar larvae of *Chrysop-*

erla carnea @ one lakh per ha at 75 and 90 days after sowing.

- Application of HaNPV @ 200 LE/ac.
- Spraying of *Bt* formulations (DIPEL, DELFIN, BIOVIT, HALT) @ 400gm or 400 ml per acre.
- *Metarhizium* (5 ml per litre water) is highly pathogenic to eggs applied in soil.
- Set up pheromone trap at canopy level for maximum attraction ex: helilure, Spodolure.
- Larval parasitoid such as *Campoletis chloridae* (Ichneumonidae); *Eriborusange-nteopilorus; Diadegmafenestalis; Bracon brevicornis; Peribacaorbataetc.*
- Use custard apple extracts or calotropis leaf liquid 4-6 ml per litre water to reduce pest population
- Use repellents like pepper + garlic 50 gm + 50 gm over night soak 20-50 ml per litre water
- Use sesame oil 2 ml per litre water during early instars to reduce leaf eating.
- Avoid shallow planting of tubers, place at a depth of 10 cm deep for PTM
- Cover the plant base with lantana, eupatorium leaves to repel and ovipositing PTM moths.

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Unlocking of Potential of Muskmelon Cultivation under Protected Environment

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Introduction

Muskmelon (*Cucumis melo* L.), a popular summer fruit valued for its sweet flavor and refreshing properties, belongs to the family Cucurbitaceae. With growing demand in both local and export markets, cultivating muskmelon under protected environments such as polyhouses offers a promising opportunity for farmers aiming to maximize yield, improve quality and extend the growing season. Protected cultivation of muskmelon presents a sustainable and profitable approach for modern horticulture, particularly in regions facing climatic uncertainties and land constraints.

Ideal Conditions for Muskmelon Cultivation

- Muskmelon thrives in hot, dry climates with ample sunlight, germinating best at temperature ranging from 28-30°C and growing well between 25-35°C.
- High humidity and continuous rainfall increase disease risk and reduce fruit quality. The crop is sensitive to cold, which slows its growth.
- Ideal soils are sandy or sandy loam with good drainage and fertility and a slightly acidic to neutral pH range of 6.0 to 6.8 is preferred for its cultivation.

Key Benefits of Protected Cultivation

- Off-season production is possible.
- Fruits remain disease-free and visually appealing.
- Better air circulation reduces fungal infections.
- Higher yields and uniform fruit quality.
- Efficient use of vertical space through hanging cultivation.

Raising a Healthy Nursery

Muskmelon can be cultivated either through direct seeding or by transplanting seedlings. Using seedling trays (84, 96 or 128 cells) filled with a sterile medium such as coco peat, vermiculite, or perlite ensures disease-free growth during the early stages.

Nursery Management

Seedling Readiness: Seedlings are ready for transplanting when they have developed 3 to 4 true leaves.

Planting System: Either a single-row or paired-row system is ideal for transplanting.

Spacing

- **Between Rows:** 1.2 to 1.5 meters
- **Between Plants:** 50 to 60 centimeters within the row

Recommended Plant Density

- **Single-row system:** Approximately 5,000 plants per acre
- **Paired-row system:** Up to 10,000 plants per acre.

Varieties ideal for protected cultivation: Popular varieties suitable for cultivation include Pusa Sarda, Pusa Sunehari, Trisha-2, Bobbsy, Sagar-60 and Kasturi,.

Post-Transplanting Care and Nutrition

Proper care in the first few weeks after transplanting sets the foundation for healthy plant development and fruiting.

Key Interventions

- Light irrigation immediately after transplanting.
- Weekly drenching with calcium nitrate (3g/L) for improved root and shoot development.
- Fungicide application (e.g., Ridomil Gold at 1.5g/L and Bavistin at 2g/L) to prevent damping-off and root diseases.
- Balanced fertilization using water-soluble fertilizers such as 19:19:19 (2g/L) and micronutrient mixtures (Combi-2 at 3g/L) to support vigorous early growth.

Training and Pruning for Enhanced Yield

To enhance fruit set and improve fruit quality in muskmelon grown under protected conditions, trellising combined with strategic pruning is essential.

1. Fruiting on Primary Branches

- Pinch the main stem at the 20^{th} to 25^{th} node stage.
- Remove all lateral branches up to the 13^{th} node.
- Retain only one fruit per primary branch, starting from the 14^{th} node, limiting to two fruits per plant.
- After fruit set, trim the tip of the fruit-bearing branch to redirect energy toward fruit development.

2. Fruiting on Secondary Branches

- Pinch the main stem early at the 4-leaf stage.
- Retain the three most vigorous primary branches and remove the rest.
- At the 13-leaf stage, prune the tips of the retained primary branches.
- Remove all secondary branches up to the 4^{th} node and allow fruiting from the 5^{th} node onward.

Fruit Load Management

- **Large-fruited varieties:** 1 fruit per primary branch (3 per plant).
- **Medium varieties:** 2 fruits per branch.
- **Small varieties:** Up to 3 fruits per branch.

This systematic approach promotes uniform fruit size, efficient nutrient allocation and improved overall fruit quality.

Fertilizer Management

Efficient nutrient management, including a well-planned basal dose before sowing or transplanting, promotes optimal growth, pest resistance and uniform fruit coloration.

Recommended Basal Dose per Acre

- FYM Compost: 5–6 tons
- Neem Cake: 200 kg
- 14:35:14 (NPK): 15 kg
- Magnesium Sulphate: 20 kg

- Bone Meal: 150 kg
- Agronomic-F: 5 kg
- Calbor: 10 kg
- MOP (Muriate of Potash): 50 kg

Fertigation Schedule after Transplanting

A stage-wise fertigation schedule ensures that muskmelons receive nutrients in sync with their physiological needs.

Stage	Days After Transplanting (DAT)	Fertilizer Composition	Dose (per acre)
5–6 Leaf Stage alternate days	17-32	19:19:19 + Urea	2kg+0.5kg
Fruiting Stage	35-55	12:61:00 / 12:52:34	2 kg
Fruit Development Stage	56-65	13:00:45	4 kg
Maturity and Sugar Buildup	66-90	16:8:24 + SOP (00:50)	5 kg

Micronutrient Management

Balanced micronutrient application supports metabolic activities and enhances fruit quality.

Application Schedule

- Calcium Nitrate (2 kg)-twice between 45-55 days
- Boron (200 gm)-twice between 55-65 days
- Magnesium Sulphate (2 kg)-twice between 55-70 days
- Micronutrient Mixture (1 kg)-twice between 55–70 days

Irigation Management

Water requirement varies with season

- **Winter:** 1.2 liters/plant/day
- **Summer:** 4 to 5 liters/plant/day
- **Average (Annual):** 2.8 liters/plant/day

Drip irrigation is the preferred method to ensure uniform water distribution and avoid water stress.

Flowering and Fruiting Behavior

Muskmelon plants typically begin flowering 35 to 40 days after transplanting. Fruits reach marketable maturity 40 to 45 days after fruit set, with the total crop duration ranging from 75 to 90 days after transplanting (DAT) for harvesting.

Pollination Management

Muskmelon is a cross-pollinated crop that relies heavily on insect-mediated pollination for optimal fruit set. In protected cultivation systems, the deployment of four honeybee hives per acre is recommended to ensure effective pollination and maximize yield.

The Hon'ble Governor of Uttarakhand, Lt. Gen. Gurmeet Singh (Retd.), visited the muskmelon crop grown under protected cultivation at the Vegetable. Research Centre, Pantnagar

Crop Health Management

Insect Pests management in Muskmelon

S. No.	Name of major Insect Pest	Salient features/Symptoms	Control measures
1	Whitefly	Found on the undersides of leaves where they feed on plant sap. Feeding by large populations can result in plant desiccation and infested plants become unhealthy with reduced fruit production.	Spray Acetamiprid @1 g/L of water OR Pegasus 1 mL/L of water
2	Mite	Mites cause the leaves to become mottled, yellow and shriveled.	Spray Omite @1 mL/L of water or Abamactin 0.5 g/L of water or Dicofol @1 mL/L of water
3	Aphid	Found on the undersides of leaves. Leaves will turn brown and die. Aphids excrete honeydew on the leaves, giving them a glossy appearance. Honeydew promotes sooty mold fungi growth, reducing photosynthesis and fruit marketability. Aphids can also transmit several viruses.	Spray Rogor 1 mL/L of water OR Imidacloprid 1 mL/L of water
4	Thrips	Suck the sap and feed on plants, causing damage and yield reductions when populations are high.	Imidacloprid 1 mL/L of water OR Spinosad 1 mL/ L of water

Diseases management in Muskmelon

S. No.	Name of major Insect Diseases	Salient features/Symptoms	Control measures
1	Powdery mildew	Whitish powdery growth on upper foliage, stems and young growing parts. The superficial spots spread and cover the entire leaf area. Affected areas turn brown and dry, causing early defoliation and death. Fruits remain under developed & deformed	Spray Saaf @2 g/L of water or Dithane M-45 2 g/L of water or Bavistin @2 g/L of water
2	Fusarium Wilt	**First symptoms:** Chlorosis of leaves. Wilting from bottom to top. Brown discoloration inside stem/root leads to plant death.	Prevent with Carbendazim + Mancozeb @2 g/L of water
3	Bacterial wilt	Initially, only a few vines may be affected. Symptoms spread rapidly. Eventually, vines become necrotic and die.	Follow proper crop rotation. Uproot and burn infected plants. Drench soil with Streptomycin @2 g/L of water or Plantomycin @1.5 mL/L of water

S. No.	Name of major Insect pest	Salient features/Symptoms	Control measures
4	Damping off	Young seedlings rot at the crown; tissue softens and plants wilt/fall.	Avoid water stagnation. Treat seeds before sowing. Drench with Redomil @1.5 g/L of water. Use plug trays for nursery.
5	Anthrac-nose	Water-soaked lesions. Later form yellowish, irregular spots. Foliage spots turn dark brown/black. On fruit, black sunken cankers appear.	Spray systemic fungicides: Saaf @2 g/L of water or Baletain @1.5 mL/L of water

Conclusion

Trellised muskmelon farming under polyhouse conditions represents a significant advancement in horticulture. It empowers farmers to cultivate crops more efficiently, achieve premium market quality and access year-round income opportunities. With proper nursery management, scientific training and pruning, and nutrient-rich aftercare, muskmelon growers can unlock remarkable productivity while conserving space and resources.

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The Art of Spring Pollination: A Symphony of Nature's Revival

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Introduction

As the Earth transitions from its winter dormancy, pollinators begin to play a pivotal role in sustaining ecosystem dynamics. Spring marks a critical period for these organisms as they emerge to facilitate the pollination of flowers, fruits and vegetables-ensuring the reproductive success of angiosperms and contributing to biodiversity and global food security (Maggi *et al.,* 2023). However, pollinators are increasingly threatened by habitat degradation, widespread pesticide application and the growing impact of climate change.Within this seasonal transformation, a remarkable ecological interaction unfolds-a mutualistic relationship between pollinators and flowering plants. As environmental conditions become favorable, bees emerge from their hives and initiate their foraging behavior, driven by the instinctual imperative of pollination.

Pollination represents a vital phase in the reproductive cycle of flowering plants, occurring through abiotic (wind and water) and biotic (animals) agents. This process facilitates fertilization, enabling fruit and viable seed production. Animal pollinators, in particular, are indispensable to plant reproduction and ecosystem resilience. Globally, more than 200,000 animal species-including bees, butterflies, moths, wasps, beetles, ants, hummingbirds and bats-serve as pollinators. Early spring presents a unique ecological challenge. Although certain plant species begin to sprout or bloom, floral diversity remains limited during this time (Kudo *et al.,* 2013). Consequently, early-season pollinators face a temporal scarcity of nectar and pollen resources. Among the first pollinators to become active is the six-spotted lichen moth (*Lycomorphapholus*), which is frequently observed visiting willow (*Salix* spp.) catkins.

Other early spring pollinators include overwintering butterfly species such as the mourning cloak (*Nymphalis antiopa*) and the satyr comma (*Polygonia satyrus*). These butterflies undergo winter diapause in sheltered microhabitats such as tree hollows, beneath loose bark, or within unheated structures, often in a cryopreserved state. As ambient temperatures rise, they emerge from dormancy and resume flight. These species are typically not frequent floral visitors; instead, their primary focus during early spring is mate location and oviposition, completing their life cycle as environmental cues signal the onset of favorable conditions. The onset of spring thus signifies more than just seasonal change-it marks a critical ecological window during which the interplay between pollinators and plants rejuvenates terrestrial ecosystems, underscoring the importance of conserving pollinator populations in the face of mounting anthropogenic pressures.

Butterflies that visit the early spring flowers include the Checkered White, Southwestern Orangetip and Spring White, which appear as pupae in winter. The larvae of all three species feed on mustard plants, including Tansy mustard and also visit mustard flowers in spring. Spring Azures are also good flower visitors.

Why is spring pollination important?

Spring marks the reawakening of the natural world, as dormant plants begin to flourish, producing blossoms that attract pollinators through their vivid colours and alluring fragrances. This season, often associated with renewal and vitality, is particularly significant for the process of pollination. It initiates the reproductive cycle for many plant species and lays the foundation for the development of numerous crops that are critical to both human sustenance and ecological balance.

In the context of agricultural systems, spring pollination is a cornerstone for the successful cultivation of a wide variety of economically and nutritionally important crops. Fruits such as apples, cherries and blueberries, as well as nuts like almonds and an array of other vegetables and edible plants, depend heavily on the activity of pollinators during this time. Bees and other pollinating insects engage in the transfer of pollen between flowers, a process that is essential for fertilization and subsequent fruit development. The absence or decline of pollinator populations during spring could significantly impair crop productivity, leading to diminished harvests and financial hardships for growers and agricultural communities.

Beyond the boundaries of cultivated lands, spring pollination also exerts a profound influence on natural ecosystems. Numerous wild plant species-including flowering herbs, trees and shrubs-rely on pollinators to complete their reproductive cycles. Bees and other pollinating animals enable these plants to produce seeds, which ensures the regeneration and long-term survival of plant populations in forests, meadows and other habitats. These plants, in turn, serve as fundamental components of their ecosystems. They provide essential resources such as food, shelter and nesting sites for a wide spectrum of wildlife, ranging from insects and avian species to reptiles and mammals.

Thus, spring pollination is not merely a seasonal occurrence but a critical ecological event. It supports the stability and productivity of both human-managed agricultural systems and wild ecosystems, highlighting the indispensable role of pollinators in sustaining life across diverse landscapes.

Challenges Facing Spring Pollinators

The ecological significance of spring pollinators-particularly bees-cannot be overstated. These insects provide indispensable pollination services that are critical for the reproduction of flowering plants, the stability of ecosystems and the productivity of agricultural systems. However, a convergence of environmental and anthropogenic stressors poses serious threats to pollinator populations globally, undermining their ability to perform this essential function.

One of the most pressing threats is the widespread loss of natural habitats. Rapid urban expansion, intensive agricultural practices and deforestation have led to the fragmentation and degradation of landscapes that once supported rich pollinator communities. These changes eliminate key foraging resources and nesting habitats, thereby reducing bee populations' viability and resilience. The decline in floral diversity and abundance directly impacts the nutrition and reproductive success of pollinators, weakening colonies and diminishing their capacity to sustain themselves across seasons.

Another critical issue is the extensive use of pesticides, particularly neonicotinoids and other systemic insecticides, which are known to have detrimental effects on bee health. These chemicals can exert both acute and chronic toxicity, impairing bees' neurological functions, navigation abilities and immune responses. In many cases, bees are exposed to these substances not only through direct contact but also indirectly through contaminated nectar, pollen and water sources. The bioaccumulative nature of certain pesticides further exacerbates their harmful effects, especially in sensitive developmental stages.

Climate change adds another complex layer of stress to pollinator populations. Shifts in global temperature patterns, altered precipitation regimes and the increased frequency of extreme weather events can disrupt the intricate synchrony between pollinators and flowering plants. In particular, mismatches in the timing of bee emergence and plant blooming-known as phenological asynchrony-may lead to reduced pollination opportunities. For example, if flowers bloom before bees become active, vital food sources may be missed and successful pollination may not occur. These temporal disruptions can reduce reproductive success in plants and affect the availability of resources for pollinators later in the season.

Collectively, these stressors-habitat loss, pesticide exposure, disease and climate variability-interact in complex ways, compounding the risks faced by pollinator species during spring and beyond. Addressing these challenges requires integrated conservation strategies that promote pollinator-friendly habitats, regulate harmful agrochemicals and consider the broader ecological consequences of a changing climate.

Conserving Spring Pollination

Safeguarding the process of spring pollination is critical not only for the well-being of pollinators but also for the health of plant communities and the sustainability of human food systems. The conservation of pollination services requires proactive measures aimed at protecting pollinator populations and the ecosystems they support. Key strategies include the restoration and preservation of natural habitats, minimizing the use of harmful pesticides and implementing broader efforts to combat climate change (Armbruster 2017).

Restoring pollinator habitats by planting diverse, native flowering species and ensuring continuous bloom periods can provide essential foraging and nesting resources. Reducing pesticide usage-particularly neonicotinoids and other chemicals known to harm bees-can alleviate toxic pressures and enhance pollinator survival. At a broader scale, mitigating climate change through sustainable land management, reduced carbon emissions and adaptive conservation practices will help maintain the ecological balance that supports pollination synchrony (Ulyshen 2025).

Individual actions also play a meaningful role in conservation efforts. Homeowners, gardeners and community members can contribute by cultivating pollinator-friendly gardens, creating nesting sites for native bees (such as undisturbed soil patches or bee hotels) and supporting sustainable farming systems that prioritize pollinator health. Purchasing products from local beekeepers and encouraging pollinator-conscious agricultural practices can further strengthen community-based conservation.

Through a collaborative approach that values the intricate relationship between flowers and their pollinators, it is possible to foster a thriving and resilient spring landscape-one that continues to support biodiversity, agricultural productivity and ecological harmony for generations to come.

Pollination process and plant-pollinator relationship

- **Missouri Master Pollinator Steward Program**

Pollination is a fundamental biological mechanism that plays a central role in the reproductive cycle of flowering plants. It stands as one of nature's most intriguing and essential phenomena. This process involves the transfer of pollen grains from the male reproductive organs (stamens) to the female reproductive structures (pistils) within the same plant or between different plants of the same species. While some plants are capable of self-pollination through abiotic means such as wind or water, the majority depend on external agents-primarily animals-for successful pollen transfer.

Pollinators and flowering plants have co-evolved to form a symbiotic and mutually advantageous relationship. Pollinators-such as bees, butterflies, birds, bats and other insects-visit flowers primarily to collect nectar and pollen for nourishment. During this process, they inadvertently carry pollen on their bodies and deposit it onto the reproductive organs of other flowers, thereby facilitating cross-pollination. This exchange not only aids in the fertilization and reproduction of the plants but also enhances genetic variability, which contributes to the adaptability and survival of plant populations over time (Galen and Storks 2017).

The process of pollination is indispensable for sustaining plant biodiversity and ensuring the stability of ecosystems. A significant proportion of flowering plant species are dependent on animal-mediated pollination, making pollinators crucial agents in maintaining ecological balance. However, in recent years, global pollinator populations have been experiencing alarming declines. This trend is having cascading effects on the plant species that rely on them and by extension, on the broader ecological systems and agricultural productivity.

The decline in pollinator abundance is largely driven by anthropogenic factors, including habitat destruction, pesticide use, monoculture farming and urban expansion, all of which contribute to the loss of diverse, flower-rich environments that pollinators require. These changes not only threaten biodiversity but also have direct consequences for human well-being, given our reliance on pollination services for food production, air quality and environmental health. Addressing this issue requires a shift in human behavior, particularly in how we manage natural spaces, gardens and agricultural lands. By adopting pollinator-friendly practices such as cultivating native flowering plants, reducing pesticide use and conserving wild habitats-we can contribute to the preservation of these vital species and support the resilience of ecosystems (Galen and Storks 2017).

- **Taxonomy basics**

Taxonomy is the scientific discipline dedicated to the identification, classification and naming of living organisms. A key reason for its importance lies in the variation and inconsistency of common names used across different regions. For instance, the mountain lion (*Puma concolor*) is also commonly referred to as a puma, cougar, or catamount, depending on the locality. Similarly, the same common name may be used for entirely unrelated species. As an example, while the pileated woodpecker (*Dryocopus pileatus*) is often simply called a woodpecker, the American woodcock (*Scolopax minor*), also known as a timberdoodle, is not a woodpecker at all despite sometimes being labeled as such. These inconsistencies in common naming highlight the necessity of using scientific names to avoid confusion and ensure accurate identification-especially when selecting or studying specific plant or animal species.

Things you can do in your own yard to help our local pollinators

- Grow a diverse array of flowering plants that bloom continuously from spring through autumn, prioritizing native species whenever possible.
- Incorporate host plants into your garden-like milkweed for monarchs or parsley and dill for black swallowtails-to support pollinators throughout every stage of their life cycle, from caterpillar to adult.
- Ensure access to clean water by adding a shallow water feature, such as a small pond or a dish with stones for insects to safely land on.
- Allow some leaves and dead plant stems to remain through the winter to provide essential overwintering shelter for various pollinators.
- Create nesting habitats for bees by preserving natural materials such as tree bark and patches of bare, sandy soil.
- Refrain from using chemical pesticides, which can harm pollinators directly or contaminate their food sources.

Conclusion

Spring pollination represents a remarkable natural phenomenon that fosters intricate interactions between plants and animals, playing a crucial role in food production and the stability of ecosystems. Pollinators such as bees, butterflies, moths and birds significantly contribute to environmental health and biodiversity. However, increasing urban development, deforestation, excessive pesticide use and climate change threaten their populations. Declines in pollinator numbers are driven by factors including the disruption of timing between flowering and pollinator activity, loss of habitat and the spread of diseases, all of which jeopardize both agricultural productivity and ecosystem balance. To mitigate these challenges, it is vital to promote the planting of native flora, minimize the use of harmful chemicals and implement farming practices that support pollinator health. Pollination is not only fundamental for boosting crop yields but also for ensuring long-term ecological sustainability. Collective awareness and concerted action are necessary to preserve environmental harmony and secure a thriving, sustainable future for coming generations.

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Government Policies Promoting ICT Use in Agriculture

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Introduction

In the face of mounting global challenges such as climate change, food insecurity, and rapid population growth, the integration of Information and Communication Technology (ICT) into agriculture has become increasingly vital. ICT offers innovative tools that can enhance productivity, improve decision-making, and increase access to markets and information for farmers. Recognizing this potential, many governments around the world have introduced policies aimed at promoting ICT adoption in agriculture. These policies play a critical role in transforming traditional farming into a modern, data-driven enterprise.

The Need for ICT in Agriculture

Traditional farming methods often rely on outdated practices that are inefficient and vulnerable to external shocks. ICT tools, such as mobile applications, geographic information systems (GIS), satellite imaging and data analytics, can help farmers make informed decisions regarding crop selection, pest management, irrigation and market trends. However, access to these technologies is uneven, particularly in rural areas. This is where government intervention becomes crucial.

Key Areas of Government Intervention

1. Infrastructure Development

Governments play a central role in building the foundational infrastructure necessary for ICT adoption. This includes expanding rural broadband and mobile network coverage to remote farming communities. For example, India's Digital India initiative emphasizes broadband connectivity in rural areas, which is essential for digital agricultural services to function effectively.

Similarly, Kenya's National Broadband Strategy aims to ensure that every citizen, including farmers in remote regions, has access to the internet. These infrastructure projects are critical for enabling the use of mobile apps, online marketplaces and weather advisory platforms that benefit farmers.

2. Policy Frameworks and Regulatory Support

Governments have developed comprehensive policy frameworks that encourage ICT adoption in agriculture. For instance, Nigeria's e-Agriculture policy promotes the use of ICT across the agricultural value chain. The policy outlines goals such as increasing farmers' access to real-time information, integrating ICT in extension services, and promoting private sector investment in agricultural technology.

In the European Union, the Common Agricultural Policy (CAP) includes provisions for supporting digital innovation in farming. It encourages member states to invest in technologies that improve farm efficiency and environmental performance.

3. Digital Extension Services

One of the most significant impacts of ICT in agriculture has been the transformation of agricultural extension services. Governments are increasingly moving from traditional, in-person extension models to digital platforms that reach more farmers at lower costs.

In India, the Kisan Call Centers (KCCs) initiative allows farmers to call toll-free numbers and receive expert advice in their local languages. These services have significantly improved farmers' access to timely and relevant agricultural knowledge.

4. Capacity Building and Digital Literacy

Adoption of ICT tools requires not only access to technology but also the skills to use them effectively. Governments have implemented training programs to build the digital capacity of farmers. These programs often focus on mobile phone use, internet browsing, and utilizing specific agricultural apps.

The Digital Green initiative, supported by various governments and NGOs, uses videos to educate farmers on sustainable agricultural practices. Farmers learn from peers through videos recorded in local dialects, making the content more relatable and effective.

5. Incentives and Financial Support

To encourage the private sector to develop and scale agricultural ICT solutions, governm-ents offer subsidies, grants, and tax incentives. Startups and agritech companies benefit from innovation hubs and public-private partnerships.

Challenges and the Way Forward

Despite these efforts, several challenges remain. Limited digital literacy, high costs of devices and internet access, and data privacy concerns can hinder ICT adoption. Moreover, gender disparities in technology access mean that female farmers are often left behind in digital initiatives.

To address these challenges, governments must continue investing in inclusive digital education, promote affordable access to technology, and ensure that ICT policies are sensitive to the needs of marginalized groups. Strengthening collaborations between governments, the private sector, and civil society can also help scale effective solutions.

Conclusion

Government policies are pivotal in accelerating the adoption of ICT in agriculture. By investing in infrastructure, creating supportive regulatory frameworks, enhancing extension services, and building farmers' digital skills, governments can drive a digital transformation in agriculture. These efforts not only boost productivity and sustainability but also empower farmers with the tools needed to thrive in an increasingly complex global food system.

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Integrated Farming for Doubling Farmer Income

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Introduction

Integrated farming, sometimes referred to as multi-dimensional farming or integrated agriculture, is a method that integrates many agricultural techniques, including crop production, animal rearing, fish farming and organic waste management, into a comprehensive and interrelated system. The various parts work together to create a system that is sustainable and synergistic. When agriculture was practiced in tandem with animals, land, water and plants, it was known as an integrated farming system. A more connected approach to farming than one-way farming techniques is generally referred to as an integrated farming system.

Objectives of Integrated Farming System (IFS)

- **Diversification of Income:** Integrating various agricultural and non-agricultural components to reduce risk and stabilize income sources.
- **Efficient Resource Utilization:** Using waste products from one component as resources for another, such as converting livestock waste into crop fertilizer.
- **Soil Conservation:** Employing techniques like intercropping and crop rotation to maintain soil fertility and prevent erosion.
- **Biodiversity Conservation:** Integrating

diverse elements like trees, crops and animals to promote wildlife habitats and conserve biodiversity.

- **Environmental Sustainability:** Adopting practices that reduce chemical inputs, conserve water and lower greenho-use gas emissions to balance environmental, economic and social goals.
- **Food Security:** Increasing food production and reducing insecurity through sustainable practices that enhance productivity and mitigate crop failure.
- **Empowerment of Small-Scale Farmers**: Providing sustainable farming practices to improve productivity and income, especially for farmers with limited resources.

Advantages of Integrated Farming System (IFS)

IFS offer numerous benefits, including

- **Increased Productivity:** By intensifying crops and integrating allied enterprises, IFS increases productivity per unit area.
- **Nutritional Security:** The integration of various production systems helps address malnutrition by diversifying food sources.
- **Improved Soil Health:** IFS improves soil fertility and structure through crop rotation, cover crops and organic compost while minimizing nutrient losses.
- **Pest and Weed Management:** Appropriate crop rotation in IFS reduces weeds, insect pests and diseases.
- **Higher Net Returns:** The integration of multiple activities provides higher net returns on land and labor resources.
- **Stable Income:** Regular income is generated from diverse products such as eggs, milk, mushrooms, vegetables, honey and silkworm cocoons.
- **Cost Reduction:** Recycling inputs from by-products of allied enterprises reduces production costs and avoids waste accumulation and pollution.

By increasing farm productivity, guaranteeing nutritional security, and generating steady income, the Integrated Farming System (IFS) tackles a number of agricultural issues. It promotes sustainable development by utilizing India's abundant agricultural diversity and national resources. IFS is a comprehensive strategy for uplifting rural communities and preserving agricultural diversity by increasing overall farm productivity, profitability, and job prospects while preserving natural resources and agro ecosystem sustainability.

Conclusion

A sustainable agricultural method known as an Integrated Farming System (IFS) blends various farming techniques, such as crop production, animal husbandry, and forestry, to produce a well-balanced and effective system. By converting waste products from one system component into inputs for another, resource utilization is maximized and environmental effect is decreased.

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Employing CRISPR-Cas Systems in Lateral Flow ImmunoAssays for Diagnosing Plant Diseases

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Introduction

Global agricultural productivity is threatened by phytopathogens like fungi, bacteria, viruses, and nematodes, reducing crop yields and endangering food security. Early detection is critical for disease management. Current methods for detecting viral infections rely on techniques like polymerase chain reaction (PCR) and its variants, including reverse transcription quantitative PCR (RT-qPCR), which amplify specific viral genetic material for analysis. Another method utilizes enzyme-linked immunosorbent assay (ELISA) to identify viral proteins. However, such approaches require a laboratory, advanced equipment and expertise. In contrast, isothermal amplification techniques such as recombinase polymerase amplification (RPA) or loop-mediated isothermal amplification (LAMP) provide user-friendly alternatives for plant virus diagnosis. Despite their lack of high specificity, these techniques offer speed, sensitivity, and need least sample processing and apparatus, making them suitable for field applications. To address specificity concerns, recent advancements have repurposed clustered regularly interspaced short palindromic repeats (CRISPR) and CRISPR-associated (Cas) proteins for diagnostic use. By integrating them with isothermal amplification methods, these systems enhance detection accuracy while maintaining the benefits of rapid results and low resource needs.

CRISPR/Cas for disease detection

CRISPR-Cas systems, derived from bacterial and archaeal immune defenses against foreign genetic material, use RNA-guided enzymes (endonucleases). Known mainly for genome editing and gene regulation in eukaryotes, they are also valuable for *in vitro* diagnostics due to their high precision and collateral DNA cleavage. CRISPR/Cas9-based detection was first used for the Zika virus, where target RNA was amplified isothermally. The viral RNA was first amplified via RT-PCR or RT-isothermal methods, followed by CRISPR/Cas9-mediated cleavage of the DNA amplicon. Results were visualized using colorimetric toehold RNA switches. An improved version of this assay employed CRISPR/Cas9-triggered exponential amplification (CAS-EXPAR), reaching attomolar (aM) sensitivity and single-base resolution. This approach distinguished between African and American Zika strains through SYBR Green-based colorimetric detection (Huang *et al.*, 2018). The identification of RNA-guided, RNA-targeting CRISPR effectors such as Cas12a, Cas13a, Cas13b and Cas14a facilitated the development of CRISPR-Cas12a, Cas13a, Cas13b, and Cas14-based nucleic methods, respectively for detecting various human-infecting viruses and bacterial pathogens. Cas13 types proved suitable for direct detection of homologous RNA targets using RNA guides, while Cas12 and Cas14 types were appropriate for detecting single-stranded and double-stranded DNA targets, respectively.

The SHERLOCK (Specific High-sensitivity Enzymatic Reporter unLOCKing) system was developed to detect target sequences using isothermal amplification methods such as Recombinase Polymerase Amplification (RPA)/Reverse Transcriptase (RT)-RPA or Loop-mediated Isothermal Amplification (LAMP)/RTLAMP (Gootenberg *et al.*, 2017). After amplification, the target amplicons were transcribed in vitro using T7 RNA polymerase, and the resulting RNA was detected via a Cas13-mediated reporter cleavage assay. Results were visualized either through lateral flow strips (colorimetric detection) or fluorometry when using fluorescent-labelled probes.

To streamline detection, the HUDSON (Heating Unextracted Diagnostic Samples to Obliterate Nucleases) technique was optimized for direct virus detection in bodily fluids, eliminating the need for nucleic acid extraction. This advancement enabled highly sensitive, rapid and equipment-free identification of viral nucleic acids, enhancing the SHERLOCK platform (Myhrvold *et al.*, 2018). Additio-nally, Cas12a and Cas12b were integrated into CRISPR diagnostics, with Cas12a targeting T-rich PAM sequences for dsDNA cleavage in the DETECTR (DNA Endonuc-lease-Targeted CRISPR Trans Reporter) system (Chen *et al.*, 2018). Target RNA/DNA was first amplified via PCR/RT-PCR or isothermal methods (RPA/RT-RPA, LAMP/RT-LAMP). The amplified dsDNA was then detected by a sgRNA-Cas12a complex, which cleaved a single-stranded DNA reporter probe (fluorophore-quencher labeled). Detection was achieved through colorimetric or fluorometric readouts (Fig. 1).

To overcome limitations like prolonged detection time and amplification-related false results, scientists introduced SATORI (CRISPR-based amplification-free digital RNA detection). This novel method integrates CRISPR-Cas13 RNA sensing with microchamber-array technology for precise diagnostics, as demonstrated by Shinoda *et al.*, (2021).

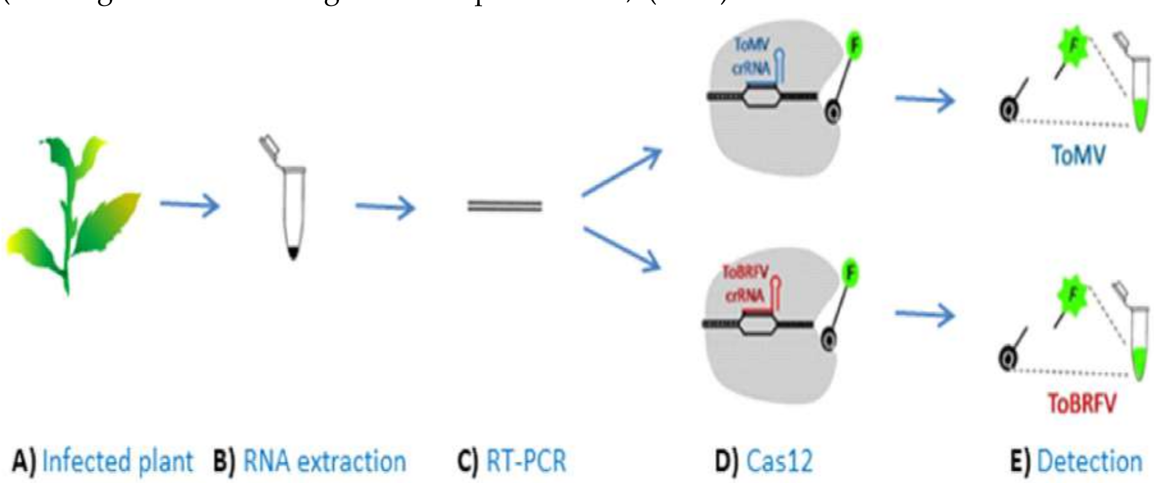

Fig. 1. Schematic representation of CRISPR/Cas12-based plant virus detection:

(A) Collection of leaf samples from symptomatic plants. (B) RNA extraction from infected leaf tissue. (C) Amplification of viral genomic segments using genus-specific RT-PCR primers. (D) Cas12a, guided by species-specific crRNAs, identifies ToBRFV or ToMV target sequences. (E) Upon target binding, activated Cas12a cleaves an ssDNA reporter probe, separating the fluorophore [F] from its quencher [Q] to generate a measurable fluorescent signal (Alon *et al.*, 2021).

On field plant disease diagnosis with CRISPR-Cas

Most CRISPR-Cas diagnostic systems first amplify target molecules through PCR, RT-PCR, or isothermal methods (such as RPA, RT-RPA, LAMP, or RT-LAMP), depending on the viral genome being detected. Target detection is then accomplished either by measuring signals from fluorophore-quencher reporter RNA probes, analyzing results on lateral flow devices, or using SYBR Green fluorescence-based systems.

Lateral flow systems offer a practical and adaptable solution for diverse applications, combining portability, simple operation, and commercial viability. These systems feature a test line containing an immobilized DNA probe designed to bind specifically to the reporter sequence on the strip. The purpose of this probe is to capture the reporters present in the sample. When the target of interest is present in the sample, a reaction occurs, leading to the cleavage of the reporter molecules. This cleavage results in a noticeable signal loss at the test line of the lateral flow strip, indicating the presence of the target. This visual indication makes lateral flow systems particularly useful for on-the-spot qualitative detection of pathogens without the need for expensive fluorescent equipment. A recent paper-based assay now combines RT-LAMP nucleic acid amplification with CRISPR-Cas12a detection for portable diagnostics. This novel approach enhances the detection capabilities of lateral flow systems, allowing for successful identification of low nucleic acid concentrations. The visual representation of assay results through lateral flow signals adds a layer of simplicity and accessi-bility to the diagnostic process. Despite their advantages, it's important to note some limitations of lateral flow systems. Firstly, they are not inherently quantitative, provid-ing a qualitative assessment of the target's presence rather than precise measurements. Additionally, there is a heightened risk of contamination in these systems, which nec-essitates careful handling and quality control measures to ensure reliable results (Fig. 2).

Table 1 provides information about various approaches combining lateral flow with CRISPR-Cas. A few of these cutting-edge techniques that effectively locate targets by combining lateral flow with CRISPR-Cas technology are briefly described. **FELUDA:** Amplicon binding is initiated by a CRISPR-Cas complex, comprising a Cas9 protein derived from *Francisella novicida* and a guide RNA labelled with either FAM (Fluorescein amidite) or FITC (Fluorescein isothiocyanate) at the terminal end. This amplicon-CRISPR-Cas9 complex is further labelled with biotin and FAM, enabling its detection using a universal Lateral Flow Device (LFD). **Biotin-Cas9-LFA:** Amplicon binding is initiated by a CRISPR-Cas complex, featuring a commercially availa-ble, biotinylated 'dead' Cas9 (dCas9 that binds to its DNA target but does not cleave it) sourced from *Streptococcus pyogenes,* paired with a guide RNA that is not labelled. The amplified product is equipped with a terminal FAM label, rendering the amplicon-CRISPR-dCas9 complex detectable through a universal LFD. **VIGILANT:** Amplicon binding is initiated by a CRISPR-Cas complex, compr-ising a fusion protein of dCas9 and VirD2 (VirD2 being a crucial protein in *Agrobacte-rium tumefaciens* involved in T-DNA processing and transfer), along with a guide RNA that is not labelled. VirD2, functioning as a relaxase, exhibits specific binding to a short FAM-labelled oligonucleotide. The amplific-ation product is equipped with a terminal biotin label, facilitating the detection of the amplicon-CRISPR-dCas9-VirD2 complex through a universal LFD.

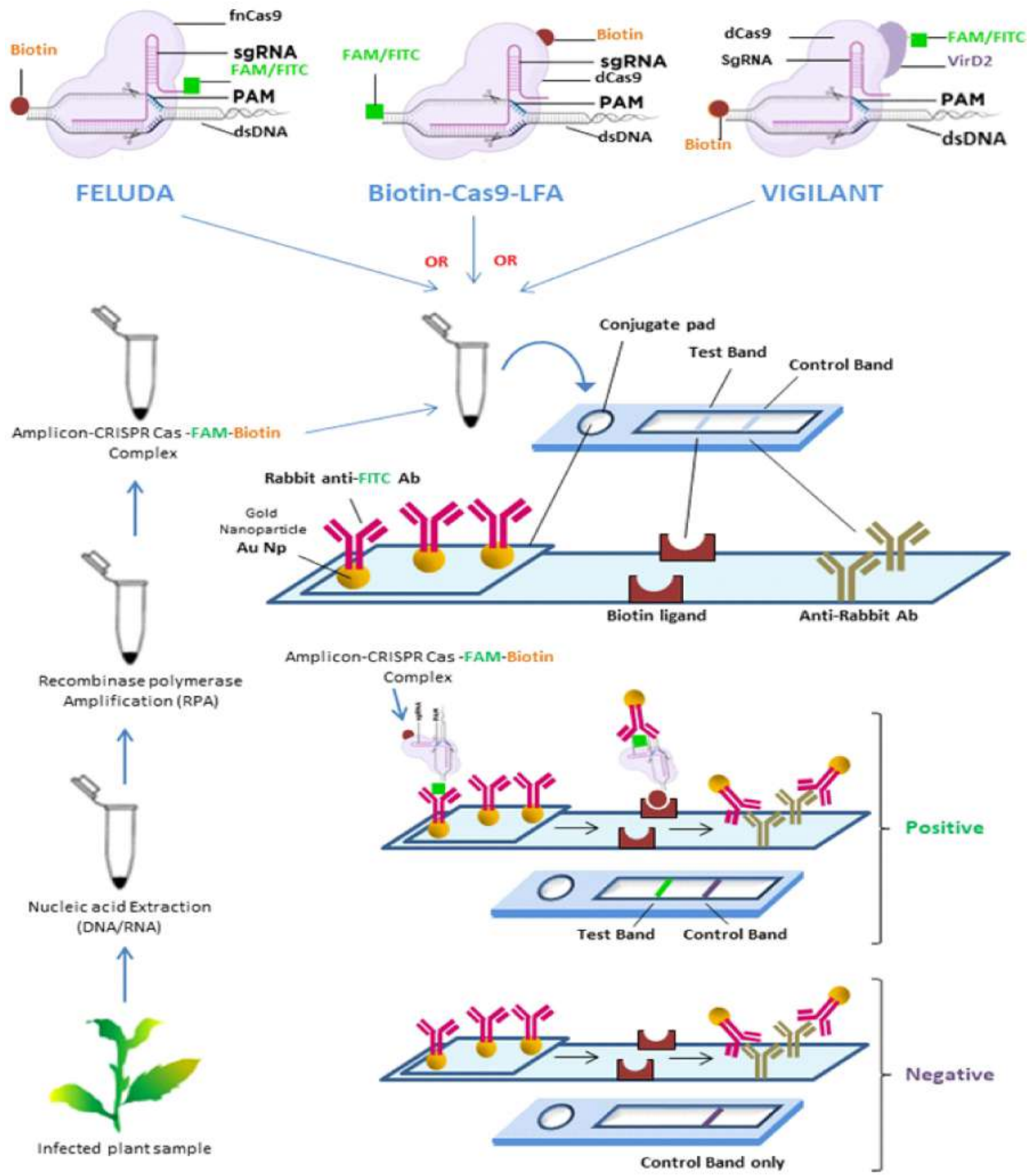

Fig. 2. Plant disease diagnosis with CRISPR-Cas through lateral flow.

Table 1: Methods combining CRISPR-Cas and lateral flow (Milenia Biotec, n.d.).

Method Name	General Detection Strategy	Amplification Method	Cas Protein (Origin)	Labelling Strategy	Lateral Flow Device
FELUDA	Amplicon Binding Assay	PCR	FnCas9 (*Francisella novicida*)	Amplicon (Biotin), gRNA (FAM)	Milenia Hybri Detect
SHERLOCK	Reporter Degradation Assay	LAMP, RPA (and in vitro transcription)	e.g. LwaCas 13a (*Leptotrichia wadei*)	Collateral Cleavage of FAM-Biotin-Reporter	Milenia HybriDetect
CASLFA	Amplicon Binding Assay	PCR, RPA	Cas9 (and d Cas9, origin unkown)	Probe- functionalized Nanoparticles, Amplicon (Biotin)	Self-made LFD
DETECTR	Reporter Degradation Assay	LAMP, RPA	e.g. LbCas12a (*Lachnospiraceae bacterium*)	Collateral Cleavage of FAM-Biotin-Reporter	Milenia Hybri Detect
VIGILANT	Amplicon Binding Assay	RPA	VirD2*-Spd Cas9** fusion protein (**Agrobacterium tumefaciens* ***Streptococcus pyogenes*)	VirD2-dCas9 (FAM), Amplicon (Biotin)	Milenia Hybri Detect
iSCAN	Reporter Degradation Assay	LAMP	LbCas12a (*Lachnospiraceae bacterium*)	Collateral Cleavage of FAM-Biotin-Reporter	Milenia HybriDetect
"Biotin-d Cas9-LFA"	Amplicon Binding Assay	RPA	SpdCas9* (*Streptococcus pyogenes*, *3xFLAG + Biotin)	SpdCas9 (Biotin), Amplicon (FITC)	Milenia HybriDetect

For BBTV (*Banana bunchy top virus*) detection, researchers have developed an Exo-RPA isothermal system that directly identifies the BBTV-R DNA segment in plant tissue, eliminating DNA extraction requirements (Kumar & Obaje, 2019). This method utilizes FAM-labeled Exo-RPA probes with fluorometric detection (Khambhati *et al.*, 2019). Current research focuses on adapting this assay into a HUDSON-SHERLOCK platform for affordable, rapid, and sensitive BBTV detection in both lab and field settings. In parallel, conventional PCR-based BSV detection methods are being upgraded to CRISPR/Cas-based diagnostics for improved identification of

BSV strains in banana plants. Due to their high specificity and sensitivity, CRISPR-based diagnostic tools have the potential to offer robust, rapid, and sensitive detection of banana viruses for seed health certification, surveillance and other applications.

Conclusion

A novel RT-RPA-CRISPR/Cas12a platform has recently emerged as a rapid one-step diagnostic tool for plant RNA virus detection (Aman *et al.*, 2020). The system employs a portable fluorescence reader for on-site virus identification, completing the entire assay in under 30 minutes at constant temperature. This breakthrough demonstrates significant potential for rapid banana RNA virus detection, enabling faster implementation of disease control measures.

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Opportunities and Challenges in Agripreneurship in India

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Introduction

Agriculture is a backbone of Indian Economy. More than 50 percent population is directly or indirectly dependent on the agriculture sector for their livelihood. The increasing demand of growing population requires enhanced agricultural productivity, sustainability & profitability. In the 21st century there is a shift from agriculture to agribusiness which embraces innovation, technology & entrepreneurship and the change makers are known as agripreneurs. As global challenges like climate change, food insecurity, and rural unemployment intensify, agripreneurs are increasingly seen as key players in creating resilient, productive, and inclusive agricultural systems. Agripreneurs is an entrepreneur whose base of business is agriculture or agriculture related sectors. Agripreneurship is the process of adopting new methods, process & techniques in agriculture & allied sectors for better output and economic earning.

The Agripreneurship opportunity can be categorized into following heads

i. Agro produce processing units: These units do not manufacture any type of new product. They merely process the agriculture produce e.g. Rice mills, Dal mills etc.

ii. Agro Produce manufacturing units: These units produce entirely new products based on the agricultural produce as the main raw material. e.g. Sugar factories, Bakery etc.

iii. Agro-inputs manufacturing units: These units produce goods either for mechanization of agriculture on for increasing manufacturing plants, e.g. Fertilizer production units food processing units, agricultural implements etc.

iv. Agro service centres: These include the workshops and service centre for repairing and serving the agricultural implement used in agriculture.

v. Agro: Food processing and storage units like Cold storages, Banana ripening chambers, minimal processing units, etc.

vi. Miscellaneous areas: Besides the above mentioned areas, the following areas may prove to be encouraging to establish agro enterprises such as setting up of feed processing units, seed processing units, mushroom production units, commercial vermincompose units, organic vegetable and fruits retail outlet, bamboo plantation etc.

Government policies and initiatives to promote agri-startups in India:

Policy/Programme	Benefit for Agri-Start ups
Startup India Seed Fund Scheme (SISFS)	Aims to provide financial assistance to startups creating innovative solutions in sectors such as social impact, care, energy, mobility, defence, space, railways, oil and gas, textiles, etc.
Agriculture Accelerator Fund	Under the programme, the financial support is provided to entrepreneurs in the field of agriculture & allied sector to set up their startups.
Rashtriya Krishi Vikas Yojna	Its objective to promote innovation and agri-entrepreneurship by providing financial support and nurturing an incubation ecosystem in the country.
Make In India 2.0	The focus of Make in India 2.0 programme is on 27 sectors. These include automobiles, electronic systems, food processing, gems and jewellery, IT & BPM, leather, media and entertainment, etc.
Atal Innovation Mission	One of the objectives of AIM is to support the establishment of new incubation centres called Atal Incubation Centres (AICs). AICs would be established in subject specific areas such as education, agriculture, water and sanitation etc.
Biotechnology Industry Research Assistance Council (BIRAC)	Set up by the Department of Biotechnology (DBT), to strengthen and empower the emerging Biotech enterprise to undertake strategic research and innovation, addressing nationally relevant product development needs.
Venture Capital Assistance	Aided financial assistance scheme in the form of interest free loan provided by the SFAC to assist agripreneurs to make investments in setting up agribusiness projects.
Pradhan Mantri Kaushal Vikas Yojana	Launched to help Indian youth take up industry-relevant skill training to get better livelihoods. Components of this scheme include Short Term Training, Special Projects and Recognition of Prior Learning.
Aatmnirbhar Bharat Abhiyan	Providing financial support to agriculture, mining and fishing industries as their primary sector.
Support to Training and Employment Programme for Women (STEP)	Scheme will be available in any sector for imparting skills related to employability and entrepreneurship, including Agriculture, Horticulture, Food Processing, Handlooms, Handicrafts, Computer & IT etc.
Aspire	Objective to set up a network of technology centres, incubation centres to accelerate entrepreneurship an also to promote startups for innovation and entrepreneurship in rural and agriculture-based industry.
Agriculture Infrastructure Fund	Objective to address the existing gaps in post-harvest management infrastructure in the country,
India Aspiration Fund	Set up by SIDBI with the support of RBI pursuant to promote & accelerate equity & equity linked investments in Start-ups

Challenges in Agripreneurship

i. Lack of education and knowledge: Most of the farmers do not have formal education; they have mostly inherited the knowledge of cultivating.

ii. Lack of entrepreneurial skills: Lack of knowledge and awareness is one of the reasons for slow growth of entrepreneurial culture in India.

iii. Lack of Awareness about Career in Agripreneurship: Entrepreneurial career has not been considered respectable in the society for one reason or other.

iv. Unresponsive Government Policies: That policy facilitates doing things in a desired and more effective manner.

v. Lack of skilled and managerial manpower: Lack of skilled and managerial manpower in rural areas is mainly due to the absence of suitable educational institutions in rural areas.

Conclusion

The present situation in the economy gives lot of scope for Agripreneurship in our country. Many agricultural and allied activities can adoptedtechnology as new opportunity in the market in an innovative manner. Agripreneurs can use these precision and innovative techniques to increase the income of agricultural produce. Agripreneurship has got power to generate growth, diversifying income, providing widespread employment and entrepreneurial opportunities in rural areas. The potentiality of the country can be tapped only by implementing effective management of agri elements such as soil, seed, water, market needs & other requirements. The situation prevailing in the economy due to the pandemic, the country has huge scope in the development of entrepreneurial skills for the farmers which will help to boost the economy. It will increase the imports provided the quality of the products is maintained which is demanded by the consumers.

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The Role of Digital Technologies in Modernizing Horticulture

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Introduction

One of the key areas of agriculture is horticulture. The production is dependent on natural factors including weather, pests and diseases, soil conditions, season and climate, and it involves live and perishable goods. A method to deal with these risks is indoor production in greenhouses, which creates a more regulated production environment to maximize light, moisture, fertigation and weather. In order to accomplish the objectives, it is necessary to continuously re-evaluate the cultivation techniques and reschedule planned activities based on timely monitoring. This is because of the uncertainties brought on by unpredictable weather patterns, pests and quality loss and new obstacles, particularly with regard to energy management.

The word "digital horticulture" is relatively new, researchers and forward-thinking producers are experimenting with a number of technologies that are now part of digital horticulture under the names of precision horticulture, climate smart technology, etc. Numerous new technologies are influencing the horticultural industry as a result of advancements in artificial intellig-ence and information technology. Horticult-ure can benefit greatly from a number of technologies, including digital twins, artificial intelligence, drones or unmanned aerial vehicles (UAVs), big data analysis, climate smart sensors, and the Internet of Things (IoT). Recognizing the potential benefits of these technologies in raising the quantity and quality of the produce, there is no dispute. Certain technologies, like e-marketing, crop area assessment and block chain management, have improved marketing opportunities for growers to increase their profits from the nation's horticultural sector.

Digital horticulture: Status and future prospects

The unpredictability of natural factors including weather, pests, soil and climate presents serious issues for horticulture. Together with advancements in digital horticulture, indoor production in greenhouses offers a regulated setting that can maximize crop development. By combining digital technologies like IoT, AI and precision farming, digital horticulture allows for increased productivity, sustainability and quality in horticultural production. Important digital tools that facilitate well-informed decision-making for crop management and resource allocation include remote sensors, drones and machine learning. In greenhouse environments, real-time monitoring, automation and remote management are made possible by IoT and digital twins. While precision irrigation systems improve water-use efficiency, as demonstrated in trials on tomato, banana, and grape crops, artificial intelligence (AI) helps with crop health assessments, pest and disease monitoring, and the best time to harvest. Additionally, digital solutions improve e-commerce, traceability, and post-harvest management. Digital innovations are anticipated to revolutionize horticulture, promoting productivity, sustainability, and climate resilience in the face of changing global food security demands, not with standing adoption obstacles brought on by high costs, restricted access and security worries.

Technologies helpful in Horticulture

- **Digital farming**

Digital farming is the integration of precision farming and smart farming, and is achieved through the implementation of intelligent software and hardware. Precision farming is popularly defined as a technology enabled approach to farming management that observes, measures, and analyses the need of individual fields and crops.

- **IoT (Internet of Things)**

This technology includes digital cameras, robotics, drones, and sensors. To capture the data, sensors, cameras and robots are positioned on the farms. Installing network-connected "smart" devices as part of the Internet of Things (IoT) or software as a service (SaaS)-based agtech are two ways to accomplish digital farming.

- **Digital twins**

Digital twins can greatly improve the necessary control capabilities by modeling interventions based on real-life data and enabling growers to take quick action in the event of (anticipated) deviations. Furthermore, greenhouse gardening has grown in size in the last few years. Manually monitoring the cultivating process is no longer feasible in large scale production. The growing lack of green labor, or seas-oned workers with horticulture expertise, serves as further evidence of this. Digital twins can be an appropriate technique to address these issues since they eliminate basic limitations related to time, location, and human observation.

- **Artificial intelligence**

The term artificial intelligence (AI) describes systems that exhibit intelligent behavior by assessing their surroundings and acting, somewhat independently, to accomplish predetermined objectives. Considering how modern it is, the vast Indian agricultural industry is also embracing it. The use of artificial intellig-ence in agricultural applications is growing in importance and integration. Its capacity to process vast volumes of data and generate precise forecasts is what makes it useful. In order to increase crop yields, optimize fertilizer and irrigation techniques, and lessen the effects of pests and illnesses, artificial intelligence is being applied. Algorithm creation is one of the main areas of artificial intelligence's application in agriculture.

- **Drone or unmanned aerial vehicle (UAV)**

An unmanned aerial vehicle (UAV), sometimes known as a drone, is a flying robot that can fly without a pilot. Software-controlled flight plans allow drones to fly autonomously or under remote control. They have high-resolution cameras, GPS, radar control, and infrared technology and they are driven by an electric motor.

Software as a service (SaaS)

Software as a service (SaaS) is the more economical and scalable way to upgrade to digital farming. Merits of digital interventions in agriculture-

- Near real-time monitoring.
- Standard package of practices.

- Readily available and accessible management through smartphones and PCs.
- Geotagging for accountability and accurate predictability.
- Satellite and weather input-based advisory.
- Robust and flexible system for farm management.
- Alert log and management of pest infestation, diseases, etc.
- Crop reports and insights- easy reporting.

Precision irrigation

Climate and edaphic elements should be taken into account while designing an effective irrigation system in order to produce a profitable and superior yield. An environmentally friendly way to manage water in banana cultivation is through the use of IoT technology. For accurate irrigation scheduling, moisture sensors assess soil moisture and provide real-time data to the cloud over the internet, where artificial intelligence processes it. Preliminary findings from the project started at ICAR-NRC for Banana, Trichy, indicate that less than 25% of water is used compared to drip irrigation without sacrificing fruit quality or yield.

Real-time pest and disease monitoring

Early disease or problem detection can be aided by the use of sensors, real-time imaging, data processing, artificial intelligence, and robots. This is due to its ability to detect any alterations in the crop's behavior or surroundings. It might notify

the employees to act right away. In addition to enhancing crop quality, this aids in disease prevention. This enhances the decision-making procedures.In a project at ICAR-NRC for Banana, Trichy, to map diseases in banana-growing regions and characterize weather factors to predict the development of pests (scaring beetle) and diseases (Sigatoka leaf spot), it was discovered that the AlexNet program had fully predicted the leaf spot disease and was integrated into a mobile application that predicts and categorizes banana leaf diseases.

Post-harvest management and food processing

At every stage of the supply chain, digital technologies may play a major role in

helping to address the issues facing the post-harvest industry. At the agricultural level, digital technologies like sensors, robotics, and drones may give farmers accurate information and assist them in raising yields in a way that is favorable to the environment. By tracking the food chain from the farm to the customer, blockchain technology can improve sustainability and traceability. At ICAR-NRC for Banana, Trichy, banana fruits are graded using CNN, which serves as a trainable feature extractor of the images, and XGboost, which identifies the ripening stage.

Challenges of digital farming

Among the difficulties include the high expense of digital farming technology, equipment, and implementation; the lack of connectivity and data availability in rural locations; and possible concerns about data security and privacy. Implementing new technologies also involves a learning curve because farmers may need some time to embrace digital farming solutions.

- High cost of adoption
- Limited access to technology

Conclusion

Digital tools are anticipated to be crucial in tackling the issues of global food security and assisting farmers in implementing climate-smart farming methods. It plays a significant part in horticulture systems since the crops have different agro meteorological requirements and range from annual to perennial in nature. This industry would become more technology-driven, productive, energy and input efficient, environmentally friendly, fully value-chain developed, and globally scalable with the help of digital smart interventions.

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Milky Amaranthus: A Resilient Leafy Vegetable for Nutrition and Sustainable Farming

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Introduction

In an era where nutrition, sustainability, and crop resilience are essential to food security, Milky Amaranthus stands out as a promising leafy vegetable offering a range of benefits. Renowned for its rapid growth, high yield, and rich nutritional profile, this improved amaranth variety is gaining increasing recognition not only in local markets but also on international platforms dedicated to sustainable agriculture and health (Dmitrieva and Ivanov, 2020).

Milky Amaranthus exhibits exceptional agronomic performance; i.e., within just 45 days after sowing, it attains an average height of 21.79 cm and produces approximately 20.79 leaves per plant. Its sturdy stem, with an average diameter of 4.77 mm, supports abundant foliage, while its root system extends up to 5.84 cm, ensuring stable anchorage and efficient nutrient absorption. Notably, this variety features a short growth cycle, allowing for the first harvest in as little as 31.33 days. This characteristic makes it particularly suitable for intensive cropping systems and urban agriculture, where rapid turnover is essential. Furthermore, Milky Amaranthus delivers an impressive yield-2.51 kg per plot, equivalent to approximately 8.33 tonnes per hectare-making it a profitable choice for both commercial producers and smallholder farmers. The variety also demonstrates a favourable benefit-cost ratio (B:C) of 2.14, reflecting a strong return on investment with relatively low input requirements.

Morphology and Anatomy of Milky Amaranthus

From a morphological perspective, Milky Amaranthus presents a striking visual and structural profile (Figure 1). It is characterized by an erect growth habit with glabrous or sparsely pubescent stems that may appear slightly reddish due to anthocyanin pigmentation. The leaves are arranged alternately and range in shape from lanceolate to ovate or rhomboid, typically measuring between 3 to 19 cm in length and 1.5 to 8 cm in width. They taper to an acute or slightly mucronate tip and have a cuneate base with entire margins. The petioles are notably long up to 15 cmand grooved along the upper surface, supporting efficient photosynthetic exposure. The inflorescence is either terminal or axillary, consisting of cymose clusters that may develop into dense, branched panicles up to 45 cm long and 25 cm wide. The flowers, which range in color from green to reddish-purple, are bisexual and subtended by a bract longer than the floral parts, contributing to the plant's aesthetic and reproductive appeal (Ebert *et al.*, 2011).

Figure 1. Seeds and Leaves of Milky Amaranthus

Anatomically, Milky Amaranthus displays adaptations that support both growth efficiency and stress resilience. The leaves exhibit a uniseriate epidermis with polygonal cells and contain multiple stomatal types: tetracytic, anisocytic, and contiguous, which aid in regulating gas exchange and transpiration. Beneath the epidermis lies a layer of collenchyma and slender parenchyma that contributes to both structural support and nutrient storage. Vascular bundles are well developed, collateral in type, and accompanied by accessory bundles, particularly evident in the midrib region where they form distinctive pentagonal to hexagonal shapes. The stem anatomy includes a prominent cambial ring and numerous collateral vascular bundles, facilitating secondary growth and enhancing the plant's transport system. Root sections reveal a taproot structure with approximately 18 vascular bundles, supporting efficient absorption and transport of water and minerals from the soil (Costea *et al.,* 2003).

Nutritional status of MilkyAmaranthus

Nutritionally, Milky Amaranthusis a powerhouse. It is exceptionally rich in Vitamin C (54.44 mg/100g), calcium (275.51 mg/100g), iron (12.21 mg/100g), and β-carotene (9.03 μg/100g), making it invaluable for addressing micronutrient deficiencies common in many developing regions (Figure 2). The leaves also offer a good amount of plant-based protein (3.62 g/100g) and dietaryfiber (0.45 mg/100g), promoting satiety, digestive health, and muscle development. Additionally, the presence of zinc (0.15 mg/100g) aids in immune function and metabolic regulation. The Total Soluble Solids (TSS) value of 3.79 °Brix contributes a mild, palatable sweetness, increasing consumer acceptance across age groups and culinary applications.

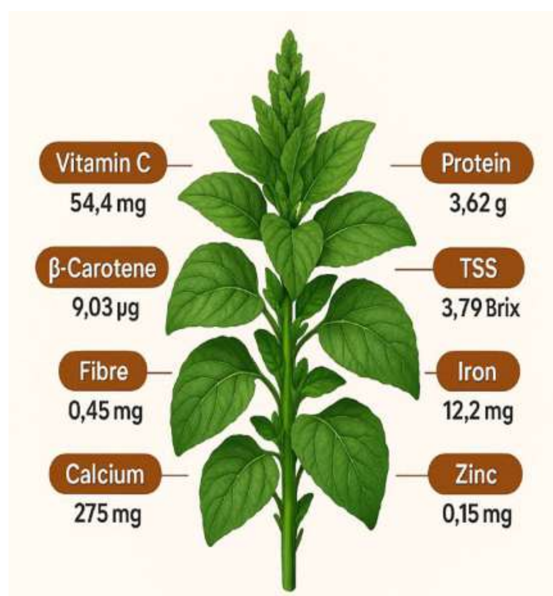

Fig. 2. Key Nutritional Components of Milky Amaranthus (/ 100g Fresh leaves)

Beyond its agronomic and nutritional appeal, Milky Amaranthusaligns well with global sustainability goals. Its ability to grow quickly with minimal inputs makes it ideal for low-resource farming systems. Its adaptability to different soil types and resilience to erratic weather patterns provide a dependable option in the face of climate change. The crop's short lifecycle also allows for multiple harvests per year, enhancing food availability and income generation throughout the seasons.

Health benefits of Milky Amaranthus

Milky Amaranthus offers a wide array of health benefits, making it a valuable addition to a nutritious diet. Rich in high-quality plant-based protein and dietary fibre, it supports muscle growth, tissue repair, and digestive health while helping to maintain healthy weight and regulate blood sugar levels. The leaves are abundant in essential minerals such as calcium, magnesium, iron, potassium, and zinc, which contribute to strong bones, improved blood formation, and overall metabolic function. Milky Amaranthus is also a notable source of antioxidants-including flavonoids, phenolic acids, and vitamin C-that help protect the body from oxidative stress, lower inflammation, and may reduce the risk of chronic diseases such as heart disease, cancer, and arthritis. Its naturally gluten-free nature makes it suitable for those with gluten sensitivities, and its high folate content supports cell formation and is especially beneficial during pregnancy. Additionally, the presence of lysine, a rare amino acid in plants, enhances calcium absorption and muscle strength. Overall, the dense nutrient profile of Milky Amaranthus promotes heart health, supports immune function, aids in digestion, and contributes to long-term wellness (Srivastava, 2017).

Conclusion

In conclusion, Milky Amaranthus is not just another leafy green, it is a symbol of smart, future-ready agriculture. Combining rapid growth, high yield, rich nutrition, and sustainability, this variety offers a practical solution to some of the most pressing challenges in modern food systems. Whether cultivated by rural farmers or integrated into urban vertical farms, MilkyAmaranthus stands as a beacon of innovation in both health and agriculture.

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AgriVoltaics 2.0: Integrating Vertical Solar Structures in Horticulture for Dual Land Use Efficiency

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Introduction

India, with its dual challenges of agricultural sustainability and energy demands, stands at a critical juncture. While traditional solar installations and agriculture have long competed for land, the emerging field of AgriVoltaics offers a synergistic solution. More specifically, "AgriVoltaics 2.0"-the integration of vertical or elevated solar structures in horticultural fields-represents a transformative leap toward maximizing land utility, crop productivity and renewable energy generation.

Understanding Vertical AgriVoltaics

Figure 1: Example of vertical AgriVoltaic system used in arid regions (Tunisia). Panels are mounted vertically between crop rows to optimize space and solar capture.

Vertical AgriVoltaics involves installing solar panels in upright or elevated configurations, allowing adequate space and light for crop cultivation underneath or alongside. Unlike conventional horizontal solar arrays that often replace farming activity, this model preserves the integrity of the agricultural space while simultaneously producing electricity.

The vertical configuration can be

- Bifacial solar panels mounted vertically between crop rows.
- Elevated solar panel structures several feet above the ground.
- Adjustable or tiltable panels that respond to sun position while maintaining crop light needs.

Suitability for Horticulture

Horticultural crops-such as leafy vegetables, herbs, and fruit-bearing plants-are often sensitive to microclimatic changes. Vertical AgriVoltaic systems offer partial shade, which can:

- Reduce evapotranspiration, saving water.
- Moderate extreme heat during summers.
- Extend growing periods for certain crops.

These effects are especially useful in regions prone to drought, high UV exposure, or temperature fluctuations.

Global Insights and Pilot Case Studies

International examples, such as from

Germany, Japan, and France, have shown promising results from AgriVoltaic farms. In India, preliminary trials by research institutes and startups in Maharashtra and Tamil Nadu indicate that vertical solar installations can increase land productivity by up to 70% when electricity output is considered.

Figure 1: Pilot project in India showing elevated solar panels with crops like turmeric and spinach cultivated beneath

A pilot project in Pune demonstrated that tomato and spinach crops grown under elevated solar structures maintained yield while the system produced 1.2 kWh/m²/day of clean energy.

Another example comes from a farm near Coimbatore, where elevated structures housing turmeric crops below solar panels reported enhanced soil moisture retention and increased net returns by 35% in a single season.

Microclimate Benefits

Vertical solar setups alter the microclimate in subtle yet impactful ways:

- Reduce wind speed at crop level, limiting physical damage.
- Create humid microzones beneficial for certain crops.
- Lower soil temperature during peak summer, enhancing root health.

These modifications can support organic farming and reduce dependency on external inputs like pesticides or mulching.

Economic Model for Smallholder Farmers

One of the most appealing aspects of AgriVoltaics 2.0 is its potential economic viability for small and marginal farmers. Shared ownership or cooperative models can make the technology accessible. Benefits include:

- Dual revenue streams (crop + energy).
- Reduced electricity bills for irrigation.
- Government incentives under solar mission schemes.

With proper training and policy support, farmers can generate passive income by selling surplus energy back to the grid.

Challenges and Recommendations

While promising, this innovation comes with implementation challenges

- Initial capital costs are high.
- Technical expertise is required for maintenance.
- Crop selection must be optimized for shaded environments.

To address these, the following are recommended

- ♦ Subsidy support and soft loans from government or agri-tech incubators.
- ♦ Research on crop compatibility under various panel configurations.
- ♦ Awareness programs and demonstration farms at the village level.

Conclusion

AgriVoltaics 2.0 is not merely an upgrade it is a revolution in how we perceive land utility. For a country like India, where land is precious and the need for renewable energy is urgent, integrating vertical solar structures into horticulture could be the bridge to a more resilient and resource-efficient agricultural future. Through policy backing, technological innovation, and grassroots adoption, this model has the potential to power both farms and futures.

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The Role of Precision Irrigation in Protected Cultivation

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Introduction

Protected cultivation is emerging as one of the most promising sectors in modern agriculture. It represents an advanced and intensive production system that primarily caters to the urban and export markets for horticultural and ornamental crops. This high-tech approach plays a vital role in ensuring food, nutritional and economic security. It refers to a technique where the microclimate surrounding the plant is fully or partially modified to shield the crop from unfavorable weather conditions. It ensures consistent yields, promotes self-employment opportunities for educated rural youth in agriculture, reduces pesticide residues, facilitates controlled pollination, mitigates the impact of unpredictable weather, aids in plant conservation and allows for weed-free cultivation.

Water is a vital input in agriculture, especially for horticultural crops that are highly sensitive to moisture stress. In protected cultivation systems like greenhouses, polyhouses and shade nets, the microclimate is carefully regulated to boost crop growth and yield. However, precise irrigation management is crucial to prevent both under-watering and over-watering, ensuring optimal plant health and productivity. This involves the accurate and targeted application of water to crops, maximizing efficiency and boosting yields while reducing water waste. This advanced approach offers a promising solution to the limitations of traditional irrigation methods, marking a significant step toward sustainable and resource-efficient agriculture.

Precision irrigation systems used in protected cultivation

Drip Irrigation System

Drip irrigation is the most effective technology for efficient water use in large-scale, sustainable horticultural crop production. It is a low-labor, highly efficient irrigation system that performs well even in challenging conditions, including problematic soils and the use of low-quality water.

The core principle revolves around delivering water directly to the root zone of plants in a slow, consistent manner through a network of tubes, pipes and emitters. The device responsible for delivering water to the plant is known as a dripper. Water is applied frequently to the soil through emitters positioned along a lateral water delivery line, which is laid close to the plant row. It typically achieves an application efficiency of 90 to 95 percent, significantly higher than the 70 percent efficiency of sprinkler systems and the 60 to 80 percent range seen in furrow irrigation.

Micro sprinkler irrigation

Micro-sprinkler irrigation, also called low-volume sprinkler irrigation, is a form of micro-irrigation that applies water at low pressure and a low flow rate, distributing it as fine droplets over a limited area.

Water is delivered above the soil surface as a spray, mist, or light rain. The system operates at a low pressure of 1 to 2.5 kg/cm^2 and typically discharges water at a rate of 20 to 300 liters per hour. It ensures uniform water distribution across a specific targeted area.

According to research by the International Center for Agricultural Research in the Dry Areas (ICARDA), micro-sprinkler irrigation systems can reduce water usage by 20% to 50% compared to traditional overhead irrigation methods.

Allows efficient fertigation and chemigation with uniform distribution. Minimizes water runoff and deep percolation losses. Ideal for both closely spaced and widely spaced horticultural crops.

Challenges

- Prone to clogging when water is not properly filtered.
- Experiences greater evaporation losses than drip irrigation.
- Demands regular maintenance and frequent nozzle inspections.
- Water distribution can be impacted by wind, leading to uneven coverage.

Sensor Based Irrigation

A precision irrigation system designed for controlled environments such as greenhouses and polyhouses, utilizing sensors and automation to regulate water application based on real-time data from plants and environmental conditions.

Benefits of precision agriculture

i) Water Use Efficiency (WUE): It reduces water wastage by delivering moisture directly to plant roots, minimizing evaporation and runoff. This precise method ensures efficient water use, conserves resources and supports sustainable irrigation practices.

ii) Crop yield and quality: Consistent and optimal water availability contributes to:

- Uniform fruit sizing
- Enhanced coloration
- Increased sugar content (TSS)
- Fewer physiological disorders

For example, in strawberries grown under a polyhouse, drip irrigation maintained optimal moisture levels, leading to a 25-30% increase in yields compared to conventional methods.

iii) Fertigation efficiency: Fertigation involves the application of soluble fertilizers through the irrigation system. When paired with precise irrigation, it delivers nutrients directly to the root zone while significantly reducing losses from leaching and runoff.

iv) Saving of energy: Energy savings enhance precision irrigation in protected cultivation by reducing pumping needs through low-pressure systems like drip or micro-sprinklers. Automation ensures efficient water use, while targeted delivery minimizes waste. Lower evaporation in controlled environments conserves both water and energy. Integration with solar-powered systems further boosts sustainability, making irrigation more cost-effective and environmentally friendly.

v) Reduced disease pressure: Overhead irrigation raises humidity and leaf wetness, creating favorable conditions for fungal diseases. In contrast, drip and subsurface irrigation keep foliage dry, helping to reduce the risk of diseases such as powdery mildew and botrytis.

vi) Smart irrigation and automation: This technology enables real-time irrigation decisions based on current crop and environmental conditions. It incorporates IoT sensors (for soil moisture, temperature and humidity), AI-driven decision-making for optimized irrigation scheduling and mobile app control to manage irrigation events remotely.

Challenges in adoption

i) High installment cost: The initial investment for drip irrigation and automation systems is relatively high due to the cost of equipment like pipes, emitters, sensors, controllers and pumps. Addition-ally, setup and technical expertise add to the expense, making it a capital-intensive option, especially for small or resource-limited farmers.

ii) Technical skills: Integrating technology into agriculture demands that farmers develop new skills and knowledge. Many, especially from older generations, may struggle with the technical aspects of operating and managing precision irrigation systems. Navigating sensors, data analysis and system calibration can be overwhelming, highlighting the need for targeted education and training programs to support farmers effectively.

iii) Power supply: Many systems depend on electricity to function and inconsistent power supply can disrupt their performance and reliability.

Future Prospects

The future of irrigation lies in the integration of smart technologies such as IoT, AI and remote sensing, enabling real-time monitoring and data-driven decisions. These advancements facilitate precise irrigation based on crop needs, soil condit-ions and weather patterns, optimizing resource use and boosting productivity. Precision irrigation also supports sustainab-ility by reducing water wastage, minimizing nutrient leaching and lowering energy consumption. As data analytics advance, farmers gain better insights for efficient crop management. Government schemes like the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) are further promoting the adoption of micro-irrigation through subsidies and support, accelerating the shift toward smarter, sustainable agriculture.

Conclusion

Precision irrigation under protected cultivation represents a transformative approach in fruit crop production, combining efficiency, sustainability and innovat-ion. By delivering water and nutrients precisely where needed, it enhances crop yield, quality and resource conservation. Despite challenges like high initial costs and technical demands, ongoing advancements in smart technologies and supportive government policies are paving the way for wider adoption. This method offers a resilient solution for future farming, ensuring food security, environmental protection and improved livelihoods for growers.

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Mulching: A Sustainable Agricultural Practice for a Better Future

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Introduction

Mulching is an important sustainable agricultural practice which conserves moisture in dry areas that also regulates temperature and lessens soil evaporation. The word "Mulching" is derived from a German word ", Molsch", which means soft to decay. It serves as a covering the surface of soil to prevent evaporation and preserve soil moisture. Farmers primarily use agricultural wastes as mulching materials such as dry weeds, leaves and paddy straw, crop residues, etc.(Yang *et al*., 2015). By 2050, the population is projected to increase to nine billion from the current seven billion. The present agricultural cultivation rates are insufficient to feed the expanding population and it may be extremely difficult for humanity to meet this anticipated demand (*Monterio* and *Santos,* 2022). As a consequence, the crop yield needs to be enhanced to meet the crop demand. However, several factors can be considered hindrances to getting an efficient crop yield. Among them, Weed is a major problem in agricultural production as they compete with the primary agricultural production for nutrients, water and sunlight, significantly reducing crop production and impeding crop growth. Herbicides or specific cultivation methods are used to mechanically control the majority of weeds. As opposed to that, herbicide use pollutes the soil, water, food and air, resulting in illnesses in people and animals, the emergence of herbicide resistance and the disruption of ecosystems. Disease and insects are other major problems in agriculture. Farmers use many varieties of agrochemicals in modern agriculture to boost productivity while safeguarding plants from diseases and insect pest attacks.

Some academics and professionals define sustainability as a collection of management techniques, while others refer to it as an ideology or a set of objectives. Eventually, Sustainable agriculture refers to "management practices that work with natural processes to preserve all resources, minim-ise waste and environmental impact, prevent problems and promote agroecosystem resilience, self-regulation, evolution and sustained production for the nourishment and fulfilment of all" (Velten *et al*., 2015).

As a consequence, mulching as a sustainable practice has been taken as the primary subject for this review paper to observe the significance of mulching not only in enhancing soil health and water retention but also in enhancing crop yields under natural and sustainable agricultural practices.

Types of mulching based on mulching material

A significant issue in agricultural practices is soil evaporation. It is a method for converting soil water into water vapour and removing it from the soil's surface. When the quantity of water readily available for transpiration at the top of the soil is infinite, it depends on meteorological factors such as radiation from the sun, the temperature of the air, atmosp-heric humidity and wind speed. That's why mulching is needed (Zribi *et al.*, 2015).

Organic mulching and inorganic mulching are the two main categories of mulching materials (Peera *et al*., 2020). The following explains the significant mulching materials used in crop production:

Organic mulch: Organic mulch is a crucial agronomic practice that has been widely used to conserve soil and water (Li *et al.*, 2020). It immediately decomposes over a period of time and is primarily composed of agricultural by-products like dried foliage, hay, shrunken bark, straw, etc. The importance of organic mulches for soil and plants cannot be overstated.

I. Compost/Manure/Peat: These kinds of mulching materials are typically used in kitchen gardens. It will raise the level of organic carbon in the soil, thereby enhancing soil fertility. It is frequently inexpensive and weed-free. Compost or manure can be easily obtained as raw materials from industrial or residential producers (Peera *et al.*, 2020)

II. Crop Residue Mulching: Mulching is suggested for areas that frequently experience drought. These materials are made from chopped crop residues and are simple to handle. The application should be done in thin layers. A smelly substance appears when the layer is very thick, which is bad for soil conditioners. These types of mulch can easily be made with the available materials.

III. Sawdust: Sawdust that has partially decayed is an essential mulch component that endures for long periods. It is highly carbonated and nitrogenated and susceptible to caking. It can't decompose easily when there is a high C: N ratio and nutritional value. Compared to the dust from hardwood, it takes longer to decompose. Primarily, it is not used until it has undergone proper decomposition, turning brown and containing worms (Peera *et al.*, 2020).

Inorganic Mulch: Inorganic Mulch differs from mulch that is organic because it is composed of components (rocks, gravels, plastics, etc.) that are unable to decompose over an extended period (Qin *et al.*, 2015). Plastic materials used in industrial crop production are included in the category of inorganic mulches. It is synthetically produced mulch. Due to it being more practical to use, the majority of synthetic mulch produced today is made from LLDPE (Bhardwaj, 2013).

I. Polythene Mulch: Films made of polyethene or polyvinyl chlorides are used as mulch. It can raise the temperature around the crops at night in winter due to its more susceptible to long-wave radiation (Bhardwaj, 2013). In the commercial production of horticulture, polythene film is used (Peera *et al.*, 2020).

II. Aluminium-coated plastic and foil: These kinds of mulch are used commercially in the production of horticultural crops and they have an impact on insect pests and infectious agents that affect vegetable crops. To control the weed, a single layer of mulch is used. However, it is highly costly and not very well-liked (Peera *et al.*, 2020).

Fig. a

Fig. b

Fig. c

Fig. a. Crop residues used as mulch on the seedbed, Fig. b. Polythene mulching for weed controlling & Fig. c. Plastic mulch for crop production

Table: An Overview of types of mulch materials

	Types of Mulch	Sub-Grouping of Mulch	Examples of Mulch	Major Roles	Commercially Used in Plant/ Region
1.	Dead Mulch	Organic Mulch	Compost/ Manure/ Peat	Increase organic carbon, soil fertility and control weeds	Kitchen garden
			Crop residue mulching	Act as an herbicide and improve the health of the soil and plants	Commercially used
			Sawdust	Control weed	Commercially used
		Inorganic mulch	Polythene mulch	Control weeds, conserve soil moisture, increase the activity of soil micro-organisms and control soil temperature	Horticultural crops (Dry semi-arid region)
			Aluminium -coated plastic and foil	Control weeds, effect on insect-pests and infectious agents	Vegetable crops (E.g. Tomato, Cucumber, Squash, etc.)
2.	Live Mulch		Legume crops	Weed control	Plantation crops(E.g. Coconut, Rubber, etc.)

Advantages of mulching

Conserving soil moisture: According to Ahmad *et al.*, (2015), mulching can lower the amount of moisture lost from the soil through evaporation and transpiration by establishing a physical barrier between the soil and the atmosphere. Kader *et al.*, (2019) stated that it improves the infiltration and water retention capacity in the soil by improving soil structure, organic matter and porosity. Mulching also lowers the soil temperature by reducing heat flux between the soil and the air, which might improve crop's capacity to withstand drought and water use efficiency (WUE).

Weed Eradication: Iqbal *et al.,* (2020) stated that Mulches act as a physical barrier to the growth of weeds and organic mulch can have allelopathic effects and produce certain harmful compounds that aid in weed control and dark-coloured plastic mulches do not allow photosynthetic active radiations (PAR) to pass through them and thus weed population reduces drastically.

Reduction of erosion and soil compaction: According to El-Beltagi *et al.,* (2022), the mulching materials shield the soil from water and wind erosion and lessen soil compaction, which can negatively impact crop roots and impede plant growth and development. Borst and Woodburn (1942) estimated that a thin covering of 0.6-inch mulch may minimise erosion by 86%.

Influence on plant microclimate: According to SK, Debnath and Maitra (2020), Limiting soil water evaporation and modifying the energy balance of the soil can affect the plant microclimate. The soil temperature near the root zone is increased by using plastic mulching.

Improves soil fertility: Several studies have shown that organic mulches such as wood chips, straw, green manures and bark provide more nutrients to the soil (Iqbal *et al.*, 2020). Ngosong *et al.*, (2019) stated that mulches with high nitrogen as well as with low nitrogen content can boost crop yield and improve soil fertility and plant nutrition.

Plant Growth and Development: Mulching is beneficial for maximising production with relatively minimal input. The establishment and survival of transplanted seedlings depend on the depth of the mulch and the age of the seedlings (kader *et al.,* 2019). Straw mulching paired with wide-precision planting is an appropriate strategy to compensate for declining winter wheat grain production and boost grain quality (Iqbal *et al.,* 2020).

Disadvantages of mulching

Expensive and labour-intensive: Mulching must be expensive and labour-intensive in a large-scale agricultural business. Mulch materials and labour costs for installation and upkeep can increase the cost, making it less affordable for most farmers (SK, Debnath and Maitra, 2020).

Increased risk of disease and pest: The mulch layer could be a source of certain diseases and pests. Slugs, snails and rodents can get shelter and protection under the mulch layer (Iqbal *et al*., 2020).

Deficiency of nitrogen: Several forms of organic mulch can temporarily bind nitrogen in the soil. Until the mulch decomposes and releases nitrogen, this nitrogen immobilisation can cause momentary nutritional deficits in plants (SK, Debnath and Maitra, 2020).

Crop overheating: Heat stress and overheating of the crop are results of using mulch materials that are dark in colour because they may both absorb and reflect heat. This is appropriate for warm areas or heat waves (Iqbal *et al*., 2020).

Conclusion

Mulching is considered one of the most necessary practices in agriculture. Mulching helps in preventing soil degradation as well as in retaining the moisture content. Other than that, mulching also helps in limiting the growth of weeds and enhances the nutrient and mineral content within the soil. Eventually, efficient approaches to mulching enhance crop yield, which is considered the most basic objective for any agriculturist. However, sustainability has become a major concern for everyone in this era. Due to heavy industrialisation and the incorporation of chemical products within the various fields, environmental pollution has become an obvious outcome of these events. Even though most of the studies suggest the use of plastic mulch materials during the process of mulching to achieve the optimum outcomes, organic mulching procedures can be adopted globally for every crop under sustainable practices. Avoiding plastic materials (non-biodegradable) can also be depicted as practices to minimise soil pollution. As a consequence, a detailed study has been covered within the review paper, on the subject topic, "Mulching as a sustainable practice". Various studies have been referred to within the paper that provide sufficient justification for how organic mulching processes enhance crop yields, throughout the globe. Hence, it is recommended to use organic and live mulches instead of plastic mulches to maintain a sustainable practice in the agricultural sector.

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Enhancing Flower Buds in L.A. Hybrid Lilium using GA_3 and BA

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Introduction

Lilium is one of the most important cut flowers in the global floriculture industry and is ranked among the top ten cut flowers worldwide. It belongs to the family Liliaceae and is valued for its use as a cut flower, potted flowering plant and landscape ornamental. In India, Lilium cultivation is primarily concentrated in Himachal Pradesh, Uttarakhand, Haryana and Jammu & Kashmir, from where flowers are supplied to both local and international markets. Among the commercially grown Lilium varieties, Asiatic, Oriental and LA hybrids are the most common. Plant growth regulators (PGRs) play a crucial role in enhancing growth, development and adaptability in floricultural crops. Among them, gibberellic acid (GA_3) and benzyladenine (BA) are extensively used to regulate flowering and plant morphology. GA_3 promotes stem elongation, internode expansion and overall plant vigor, particularly in bulbous crops (Singh *et al*., 2018). It also enhances bulb and bulblet development, essential for Lilium productivity. Meanwhile, BA, a synthetic cytokinin, stimulates cell division, delays senescence and improves flowering potential (Sathyanarayan & Divya, 2019). Given the significant role of GA_3 and BA in floral crop production, their application in LA hybrid Lilium under protected cultivation could be a promising approach for enhancing flower bud production and overall floral yield.

L.A. Hybrid Lilium

Lilium is a highly valued ornamental bulbous crop known for its economic viability, vibrant colors and extended vase life of up to one week. Among hybrids, L.A. (Longiflorum × Asiatic) hybrids and L.O. (Longiflorum × Oriental) hybrids have gained commercial importance, with L.A. hybrids gradually replacing Asiatic hybrids due to their superior traits.

L.A. Hybrid introduced in 1992, L.A. hybrids combine the hardiness and bright colors of Asiatic lilies with the strong stems, larger flowers and longer vase life of Longiflorum lilies. They produce vibrant, upward-facing flowers in shades of orange, yellow, violet, white, pink and red, with little to no fragrance. Highly adaptable, they thrive in diverse climatic conditions, exhibit strong disease resistance and have an extended post-harvest life, making them ideal for the cut flower industry.

Due to their high bud count, superior flower quality and suitability for protected cultivation, L.A. hybrids have become a preferred choice for commercial floriculture worldwide.

Plant Growth Hormone (PGRs)

The introduction of plant growth regulators (PGRs) has significantly impacted the floriculture industry by enhancing plant growth, flower quality and adaptability to environmental conditions. PGRs are chemical compounds that regulate physiological processes such as nutrient uptake, resistance to pathogens and responses to light and temperature. Synthetic PGRs, including auxins, cytokinins, gibberellins and ethylene promoters, are widely used to improve growth and flowering characteristics in floricultural crops.

Among these, gibberellic acid (GA_3) plays a crucial role in increasing flower yield and enhancing quality attributes such as flower size, stem elongation and vase life. The exogenous application of GA_3 has been found to improve market-desirable traits by promoting cell elongation, stimulating flowering and influencing reproductive growth. On the other hand, cytokinins, which are naturally produced by plants, regulate essential processes like cell division, shoot proliferation and leaf senescence. Benzyl adenine (BA), a synthetic cytokinin, is widely incorporated into commercial PGR formulations to enhance lateral bud growth, delay aging in leaves and flowers and improve nutrient utilization efficiency.

Although GA_3 and BA both influence plant growth and flowering, they function through different mechanisms. GA_3 primarily promotes elongation growth, affecting stem height and flower bud expansion, whereas BA stimulates cell division and shoot formation, leading to increased branching and a higher number of flower buds. The application of GA_3 generally results in taller plants with larger flowers, while BA ensures compact growth with more lateral shoots and uniform flowering. The appropriate balance between these PGRs is essential for optimizing flower quality and achieving desirable plant morphology.

Assessment of GA_3 and BA for enhancing flower bud production

To evaluate the effects of GA_3 and BA on flower bud production in Lilium, different treatments were applied, viz: GA_3 @ 100 ppm, GA_3 @ 150 ppm, BA @ 100 ppm, BA @ 200 ppm, GA_3 100 ppm & BA 100 ppm, GA_3 100 ppm & BA 200 ppm, GA_3 150 ppm & BA 100 ppm and GA_3 150 ppm & BA 200 ppm.The experiment was conducted with three replications. Foliar application was practiced 30 to 45 days after plantings.

Table 1 – Effect of different concentrations of GA_3 and BA on number of buds per plant of lilium

Treatments	Number of Buds Per Plant
T0	6.66
T1	6.89
T2	7.44
T3	7.33
T4	6.88
T5	7.77
T6	7.66
T7	8.22
T8	8.86

Fig. 1 Bud initiation stage of lilium

Results indicated that the highest number of flower buds was observed in the GA_3 150 ppm & BA 200 ppm treatment, with an average of 8.86 flowers per plant, followed by GA_3 150 ppm & BA 100 ppm, which produced 8.22 flowers per plant. The lowest bud count was recorded in the control treatment, with an average of 6.66 flowers per plant.

Fig. 2 ***Lilium L.A. Hybrid*** **(var. Brindisi)**

The combined application of GA_3 150 ppm & BA 200 ppm significantly increased flower bud production in liliumcompared to the control. The synergistic effect of these growth regulators may play a crucial role in stimulating bud initiation and development. These insights can help optimize plant growth regulator applications for commercial lilium cultivation, leading to improved flowering performance and higher ornamental value.

Conclusion

This study focused on the significant role of PGRs, particularly GA_3 and BA in enhancing the number of flower bud production in L.A. Hybrid lilium under protected cultivation. From the findings the combined application of GA_3 (150ppm) & BA (200ppm) shows more number of buds per plant (8.86), followed by GA_3 (150ppm) & BA (100 ppm) with 8.22 number of buds per plant and the least was shown by the control (6.66). These results underscore the synergistic effect of GA_3 and BA in promoting bud initiation and development, which is critical for improving flowering performance and ornamental value.

The findings suggest that the strategic use of GA_3 and BA can significantly enhance the commercial production of L.A. hybrid Lilium, particularly in protected cultivation systems. This approach not only increases flower yield but also improves the overall quality of the flowers, making it a viable option for growers aiming to meet market demands. Future research could focus on optimizing the timing and frequency of PGR applications, as well as their long-term effects on bulb development and post-harvest quality, to ensure sustainable and profitable cultivation practices.

In conclusion, the integration of GA_3 and BA into the cultivation protocol for L.A. hybrid Lilium offers a promising avenue for boosting productivity and economic returns in the floriculture industry.

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Apomixis - A hopeful Route for Crop Improvement

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Introduction

Combining high-yield varieties with high-input agronomic approaches to generate a remarkable yield gain has been one of the greatest agricultural success stories in modern times, a phenomenon known as the "Green Revolution". Throughout history, crop plants have typically undergone a consistent pattern of introduction, selection and hybridization. Following introduction, new cultivars with enhanced production and adaptability have been created through breeding and selection techniques. Through increased selection, the development of hybrid varieties in additional crops and the use of transgenic breeding and mutation to expand the range of plant functions, plant breeders are attempting to carry on the Green Revolution. Alleles spread in the progeny of out crossing species, leading to the loss of both the desired trait and the ideal genotype. Vegetative propagation can be used to create exact duplicates of a superior genotype, although it is typically not suitable for annual crops. The fixation of a particular genotype happens spontaneously in organisms that produce seeds asexually, a process known as apomixis. Even though apomixis is a highly desirable characteristic for agriculture on its own, modern domesticated crop species have not been able to include it, despite numerous attempts. An excellent characteristic in contemporary agriculture is apomixis, which is a reproductive approach for cloning plants from seeds. As apomixis produces embryos from the parthenogenic development of apomeiotic egg cells, the progeny are indeed genetically identical to the mother. Apomixis can be viewed from an evolutionary perspective as a result of sexual failure as opposed to a guide to successful cloning.

Long-standing objectives of plant breeding include the introduction of apomixis from wild relatives into crop species and the conversion of sexual genotypes into apomictically reproducing genotypes. Apomixis's introduction into crops that are significant to agronomy is predicted by breeders to have revolutionary effects on agriculture. Using apomixis to its full capacity could have a wide range of advantages, from clonally propagating the superior genotypes in seed-propagated outcrossing crops to fully utilizing heterosis by reseeding the best hybrids. Clonal crop propagation may also benefit from apomixis technology. Pathogens, primarily viral and endophytic, accumulate throughout multiple rounds of vegetative propagation and severely restrict the yield and cross national exchange of germplasms, hence severely limiting clonal crop yields. By using apomixis technology, these crops would also benefit from the extra option of clonal seed propagation, which would produce disease-free material that is easier to store and transport. Similar advantages (such as cheaper costs and higher yields) would be obtained from using apomictic seed instead of vegetative propagules as opposed to the existing practice of using real seed of such crops. For instance, apomixis technology could increase the appeal of real potato seeds to cultivators and breeders and provide growers with annual benefits of up to 2.3 billion euros. (Spillane *et al*., 2004)

Two types of apomixis found; Sporophytic apomixes (or adventitious embryony) and gametophytic apomixis. An embryo that grows straight from non-embryonic cells, including those in the ovule, without the need for fertilization is known as sporophytic apomoxis, a type of asexual reproduction in plants. A new plant embryo develops from the parent plant's somatic cells throughout this process, frequently in reaction to external stressors or conditions.

Considering that the progeny are descended from the tissues of a single parent plant, this could result in the creation of genetically identical children. Gametophytic apomixis is the term for the apomictic process, which results in a maternal embryo from a diploid egg cell that has developed in an unreduced embryo sac (Nogler, 1984). In gametophytic apomixis, a somatic nucellar cell that obtains the developmental program of a functioning megaspore a process known as apospory may give rise to the unreduced embryo sac. If, on the other hand, the megaspore mother cell exhibits modified or repressed meiosis during the formation of the embryo sac, this process is known as diplospory. Emphasizing that apomictic plants activate the gametic cell destiny either in a somatic cell (apospory) or in an unreduced megaspore (diplospory) as a stand-in for meiotic products is important. Apomictic plants may or may not alter meiosis itself (Albertini and Barcaccia, 2007). On the basis of haploid and diploid, diplospory is further divided into parthenogenesis and apogamy. In parthenogenesis, embryo directly develop from embryo sac without fertilization. In apogamy, embryo develops from haploid nuclei other than egg cell (it might be synergid cell or antipodal cells). While diplospory has been observed in *Agropyrum, Allium, Antennaria, Boechera (formerly Arabis), Datura, Eragrostis, Erigeron, Eupatorium, Ixeris, Parthenium, Paspalum, Poa, Taraxacum*, and *Tripsacum, apospory* has been documented in *Beta, Brachiaria, Centchrus, Chloris, Compositae, Eriochloa, Heteropogon, Hieracium, Hyparrhenia, Hypericum, Panicum, Paspalum, Penniset-um, Poaceae, Ranunculus, Sorghum, Themeda* and *Urochloa* (Barcaccia and Albertini, 2013).

Crop enhancement using Apomixis

In commercial agriculture, plants are carefully chosen from a vast array of naturally occurring flowering plant species, and wild species continue to play a crucial role as sources of genetic material in breeding and molecular crop improvement programs. The success of modern agriculture heavily relies on the consistent quality of seeds and fruits. This demand for uniformity in product quality poses a challenge to natural sexual reproductive mechanisms, which have evolved to promote genetic diversity. In agricultural systems, sexual reproduction also brings risks related to fertilization processes. When plants have unisexual or self- incompatible blooms, fertilization becomes challenging since pollinator behavior and the simultaneous blooming of a compatible variety depend on factors such as farm design and environmental circumstances. Therefore, these issues might be avoided and more control over the consistency of agricultural yield could be achieved if crops could be produced without the need for pollination or fertilization. In plants, clonal reproduction by seed which is not dependent on fertilization is real. This type of reproduction is frequently seen in some angiosperms through a process known as apomixis. Apomixis, an asexual process of seed reproduction, has special potential for the future development of superior cultivars. It can be found in closely related species of many cultivated crops and appears at low levels in some farmed species. The generation of true-breeding hybrids and commercial hybrid produc-tion without the need for expensive, labour-intensive proce-dures or cytoplasmic male sterility would be made possible by the transfer of apomixis to essential crops. In the event of heterozygosity, obligatory apomictic hybrids would reproduce as intended. It might also offer a productive way to assess genetic stability and add genes to novel genotypes. The only way to get conclusive proof of apomixis presence or absence is to thoroughly screen a large number of plants in a variety or hybrid. With ovule microtomy, the screening process entails a methodical and meticulous tracking of the processes that lead from megaspores to embryonic developments in the development of the embryo-sac and embryo. Notably, though, only recurring apomixis that is, diploid types of apospory, parthenogenesis, apogamy, adventive embryony, and vegetative propag-ation is advantageous for the breeding of plants. The straight forward explanation is that it can continue to exist for many generations as it can create viable diploid embryos without fertilization. Academic use only pertains to non-recurrent apomixis (Khan *et al.*, 2015).

Utilizing Apomixis for Plant Breeding

If there are sexual and apomictic plants that are cross-compatible and apomictic proge-nies that can be recovered in the F1 or in subsequent generations, then breeding apomictic cultivars should be feasible in any species. Due to the heterozygosity of the apomictic parents, sexual × apomictic crosses typically release a significant amount of genetic diversity. Unless the obligatory apomict is crossed as a male parent with a sexual plant, the heterozygosity in the apomict is typically not released. Simple inheritance, domin-ance, obligate express-ion, environmental stability and normal embryo and endosperm formation are ideal traits for genes regulating apomixis in a breeding program. Choose the species or genotype with the highest number of these traits will improve the effectiveness of using apomixis in crop development because different genus-to-genus variations in expression and mechanisms may exist (Hanna and Bashaw, 1987).

The breeding strategy will mostly depend on the inheritance of the gene or genes causing apomixis. Studies have indicated that apomixis is often regulated by a small number of genes, which may be dominant or recessive (Bashaw, 1980).

Recessive gene-controlled apomixis can be introduced into a cross by a male parent or a female parent who is heterozygous for the reproductive strategy. Both sexual and apomictic plants will be present in the resulting progeny. Moreover, selfing allows a sexual plant that is heterozygous for one reproductive technique to produce more apomictic and sexual offspring. Either the F or selfed generation of superior obligatory apomictic plants would breed true and be prepared for performance testing. Breeding protocols for partially dominant or recessive genes have been described (Taliaferro and Bashaw, 1966).

Only an apomictic male parent can introduce apomixis controlled by dominant gene(s) into a cross. Due to the fact that most apomicts are heterozygous for the mechanism of reproduction, the resulting sexual × apomictic progenies will typically comprise both sexual and apomictic plants. Repetitive crossings of superior apomictic male pollinators with superior sexual plants should enable further improvement. Every generation, superior obligate apomictic plants would be chosen to represent possible new cultivars. Within and across species and genotypes, apomictic reproduction can range in degree from obligatory to facultative (partially sexual), with differing degrees of apomixis. The ideal mechanism for application in plant breeding is obligate apomixis. In order to enhance the frequency of apomixis, it may be necessary to take more challenging measures, such as inter-crossing plants with the greatest levels of apomixis. In order to choose the optimal apomicts and assess genotypes for genetic stability, further progeny testing with facultative types is required (Hanna and Bashaw, 1987).

Signs of Apomixis

It's likely that farmed species have more apomixis expressed to varying degrees than has been documented. One may easily ignore apomixis as a reason for unusual genetic crossing or segregation outcomes. Certain helpful apomixis markers should be investigated further using cytological techniques, progeny testing and/or more thorough crossing. The following are departures from typical breeding behaviour that may indicate apomixis in both farmed and wild species:

- Plants of cross-pollinated species that produce uniform offspring or some identical maternal progeny. A quick way to screen a lot of accessions is to use seeds from open- pollinated inflorescences in a progeny test.
- Differing mother types in the offspring of F1 crossings. It could be necessary to conduct cytological investigations on the mother parent and rule out issues with crossing procedure in order to confirm apomixis.
- Minimal or non-existent genetic diversity in an F2 offspring resulting from a union of two different parents.
- Recessive genotypes resulting from pollination with a parent homozygously dominant for the marker gene, crossing an expected apomictic genotype with a recessive gene.
- Exceptionally high seed fertility in plants that should be sterile, such as wide crosses, aneuploids, and triploids.
- The number of aneuploid chromosomes or structural heterozygosity that is carried over from parent to offspring.
- Numerous stigmas, numerous ovules per floret, several seedlings per seed, and double or fused ovaries (Hanna *et al*., 1970; Hanna and Powell, 1973).

More thorough and precise testing should be done if one or more of these apo-mixis indications are found. One way to do this would be to pollinate suspected apomictic plants that are homozygous recessive for the same marker gene using pollen from plants that are homozygous for a dominant marker gene. It is necessary to emasculate in some way. The degree of apomictic, or maternal reproduction, is shown by the proportion of plants in progenies for these crossings that have the recessive gene. Moreover, cytological findings can be utilized to ascertain the apomictic mechan-ism and validate apomictic reproduction. Methods like the ones described by Young *et al*., (1979) make cytological observation quick.

Methods of Apomictic Plant Isolation

There are five different methods for separating apomictic plants (Spillane *et al*., 2004)

- **Morphological:** Homogeneity of offspring from parents who are cross-pollinated or heterozygous. parental traits appearing in crosses
- **Cytological:** Cytological investigation is performed on growing embryo sacs at

various phases, ranging from MMC initiation to the creation of mature embryo sacs.

- **Histopathological:** Various stages of maturation of female florets are gathered. After being fixed in FAA for a whole day, they are moved to 70% ethanol. Using the ovule-clearing technique, pistils are separated and dried. The parafilm-embedded pistils are sectioned at a 10 mm interval and stained with safranin O-fast green.
- **Biochemical:** Isozyme markers can be used to identify apomixis and investigate genetic variation. Using enzyme electrophoresis, the apomictic breeding behavior of Allium tuberosum was identified.
- **Molecular:** Breeding material can be tested for apomixis if the apomixis genes can be marked using molecular markers like RAPD, RFLP or AFLPs.

Apomixis's benefits for Plant breeding

When plants reproduce by amphimixis, the two sexual processes self and cross-fertilization followed by segregation often result in changes to their genetic makeup. In these kinds of plants, inbreeding and unchecked outcrossing also have a tendency to undermine heterozygote superiority. Apomicts, on the other hand, typically preserve their carriers' genetic makeup. They can also continue to benefit from heterozygote advantages for several generations. Consequently, in plant breeding, when the most desirable outcome is genetic homozygosity (in varieties of selfers) or heterozygosity (in hybrids of both selfers and outbreeders), such a mechanism may provide a significant advantage. Furthermore, because apomixis prevents fertilization, it results in the perpetuation of just maternal people and maternal traits, which may have an early or delayed impact on the effective exploitation of maternal influence, if any, reflected in the progenies that follow. Horticultural crops, especially fruit trees and ornamental plants, are most frequently affected by maternal impacts. So, to summarize, the advantages of apomixis in terms of their use in plant breeding are as follows: (1) It is possible to quickly multiply genetically homogeneous individuals without running the risk of segregation and (2) It is possible to permanently fix heterosis or hybrid vigour in crop plants, which eliminates the need for repeating the production of F1 hybrid seeds. (3). From generation to generation, the maternal influence, if it exists, can be effectively utilized. (4). Because homozygous inbred lines, like those in corn, occasionally produce viable gametes and seeds in addition to sectors of diploid tissues, they can develop quickly. Through the process of apomixis, hybrid vigour can be fixed during the manufacture of clonal seeds, allowing for the affordable and continuous production of clonal seeds for a particular market niche. This technique is essential for plantation timber, heterozygous fruit tree crops and seed-propagated crops. First-generation offspring of genetically distinct plants, hybrid cultivars display hybrid vigour, which is a desired trait. Genetic segregation prevents hybrid cultivars from being used as seed sources for subsequent generations. By doing away with male-sterility lines and line isolation, as well as cutting expenses and outcross contamination, apomixes streamline the creation of hybrid seeds (Hanna and Bashaw, 1987). On the other hand, plant variety is currently used. One environme-ntal issue has been raised regarding genetic-ally modified (GM) crops and their ability to spread foreign genes to related plant species through pollen. Up till further research is conducted on the effects of novel genes on native plants and weeds, future generations of genetically modified crops will probably need to use containment techniques due to practical and legal concerns. Up until now, the majority of molecular strategies that have the potential to regulate gene flow between crops and weeds have concentrated on three factors: male sterility, maternal inheritance and seed sterility. Other containment techniques, including as apomixis, cleistogamy, genome incompatibility, chemical induction/deletion of transgenes, fruit- specific excision of transgenes and tran-sgenic mitigation, may also be helpful in limiting gene flow (Daniell, 2002).

Conclusion

Apomixis has the potential to completely transform crop improvement in commercial agriculture. Apoptism provides a means to create genetically homogeneous individuals with fixed hybrid vigour without including sexual reproduction, which eliminates the need to repeatedly manufacture F1 hybrid seeds. Apomixis can be used to propagate clones, create homozygous inbred lines quickly, and produce clonal seeds continuously. These features are very helpful for plantation wood and heterozygous fruit tree crops. Furthermore, apomixis addresses issues with gene flow in genetically modified crops and expedites the generation of hybrid seeds. Nonetheless, a complete comprehension of its principles, exact breeding tactics and efficient techniques for detecting apomictic plants are necessary to fully realize the potential of apomixis in crop improvement. With further research and technological advancements, apomixis could emerge as a cornerstone of sustainable and efficient agriculture in the future.

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Shree Anna: Millets as the Future Superfood-Opportunities for Farmers and Entrepreneurs

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Introduction

In recent years, there has been a global shift toward healthier and more sustainable diets. One crop family making a powerful comeback in this movement is millets, known as Shree Anna in India. With ancient roots in Indian agriculture, millets are now being recognized not only as a nutritional powerhouse but also as a climate-resilient crop with vast economic potential. The Indian government's push during the International Year of Millets 2023 has brought renewed attention to these grains, positioning them as the next big opportunity for farmers and entrepreneurs alike. This article highlights various health benefits and growth challenges of millets with case studies of farmers and entrepreneurs.

Fig. 1: Types of Millets

Health Benefits of Millets

Millets are often termed "nutri-cereals" due to their impressive nutritional profile. Compared to rice and wheat, millets are richer in fiber, protein, essential amino acids, vitamins and minerals.

a) Rich in Nutrients

- High fiber content helps in digestion, weight management and lowering cholesterol.
- Low glycemic index makes millets ideal for managing diabetes.
- Essential minerals like iron, calcium, magnesium and phosphorus contribute to bone health and immune function.
- Gluten-free nature makes them suitable for people with celiac disease or gluten intolerance.

b) Disease Prevention

Regular consumption of millets has been associated with reduced risks of:

- Cardiovascular diseases
- Type 2 diabetes
- Obesity
- Certain cancers

Additionally, millets have a satiety-inducing effect, helping reduce overall calorie intake, making them ideal for urban populations battling lifestyle disorders.

c) Versatile Culinary Use

Millets can be used in various forms-porridge, flour, noodles, snacks and even beverages. This adaptability makes them ideal for both traditional diets and modern food innovations.

Climate Resilience of Millets

In the face of climate change, millet cultivation offers critical advantages for sustainable agriculture.

a) Drought-Resistant and Low Water Requirement

Millets are hardy crops that thrive in arid and semi-arid regions with minimal water, making them perfect for areas affected by erratic rainfall and water scarcity. Unlike water-guzzling rice and wheat, millets need 70% less water and can survive in poor soil conditions.

b) Short Growing Season

Most millet varieties mature within 70–90 days, allowing farmers to grow them even between two cropping cycles. This makes them a useful crop for improving food security and income in marginal areas.

c) Resilient to Pests and Diseases

Millets are naturally resistant to many common pests and diseases, which reduces the need for chemical pesticides and supports organic farming practices.

d) Environmental Benefits

Millet cultivation improves soil structure and fertility through crop rotation. The reduced input requirements (less fertilizer, fewer pesticides) mean lower greenhouse gas emissions, contributing to eco-friendly farming systems.

Market Potential of Millets

The millet economy is undergoing a rapid transformation due to rising consumer demand, policy support, and innovation in food processing and packaging.

a) Rising Global and Domestic Demand

With the superfood trend catching on globally, there's increasing demand for alternatives to refined grains. Millets are now being recognized in urban wellness markets, both in India and abroad. Countries like the USA, German and the UAE have become key export destinations for Indian millets. The Indian government has rebranded millets as "Shree Anna" and is investing in marketing, R&D and supply chain infrastructure. E-commerce platforms, organic food brands and restaurants are incorporating millet-based products into their offerings.

b) Entrepreneurial Opportunities

Millets open up a wide spectrum of agri-business ventures:

- **Processing Units:** Cleaning, grading, de-husking and milling of millets
- **Product Development:** Ready-to-eat (RTE) snacks, breakfast cereals, flour blends, health bars
- **Direct-to-Consumer Brands:** Millet-based food startups targeting urban wellness markets
- **Export Businesses:** With GI tags and organic certification, Indian millets are positioned well for international markets.

Entrepreneurs can also explore agri-tourism, value-added products and food innovation using millets as the base.

c) Policy and Institutional Support

The Indian government has rolled out numerous initiatives to promote millets:

- National Year of Millets (2018) and International Year of Millets (2023)
- Inclusion of millets in PM POSHAN (Midday Meal) and PDS (Public Distribution System)
- Subsidies and incentives for millet cultivation and processing
- Start-up funding and incubation support through agri-tech and food processing schemes.

These measures provide a fertile ecosystem for start-ups, farmer producer organizations (FPOs) and rural youth to enter millet-based entrepreneurship.

Challenges and the Road Ahead

While the potential is high, several bottlenecks need addressing:

• Consumer awareness remains limited outside health-conscious segments.

• Processing infrastructure is underdeveloped, especially in rural areas.

• Storage and shelf-life of millets are lower than polished grains like rice and wheat.

• Market linkages between farmers and buyers need strengthening.

To overcome these, targeted interventions are required:

Mass awareness campaigns and culinary innovations, Investments in rural processing units and logistics, Support for FPOs and women-led millet enterprises, Strong branding and international promotion of "Shree Anna" products

Economic Empowerment and Inclusive Growth

Millets offer more than just nutritional and environmental benefits-they also play a critical role in inclusive rural development and economic empowerment, especially for smallholder farmers, women, and tribal communities.

a) Boosting Farmer Incomes

Millets require fewer inputs (like fertilizers and irrigation), reducing production costs. With increasing demand in domestic and export markets, millet farmers can fetch better prices, especially when linked to FPOs or niche markets like organic and fair trade.

When compared to water-intensive crops, millet cultivation is more economically viable in drought-prone areas like Rajasthan, Maharashtra and parts of Karnataka and Telangana.

b) Empowering Women and Marginal Farmers

Millet farming is often carried out by women farmers in tribal and backward regions. Promoting value addition, micro-enterprises and self-help groups (SHGs) around millets can:

• Create local jobs

• **Improve women's incomes and autonomy**

• Enhance rural food security

Women-led initiatives like preparing millet-based snacks, papads, flours and sweets are becoming popular in state-level fairs and online marketplaces.

c) Millet Cooperatives and FPOs

Farmer Producer Organizations (FPOs) can aggregate millet produce, negotiate better prices and set up community-owned processing units. With adequate training and support, they can also explore direct marketing and branding.

Case Studies and Success Stories

Case Study 1: Odisha's Tribal Women and Ragi Cultivation

The Odisha Millet Mission has empowered thousands of tribal women by supporting ragi (finger millet) cultivation through SHGs. Women are now processing and selling ragi laddus, cookies and malt drinks in urban markets. The initiative combines nutrition security, livelihood and women's empowerment.

Case Study 2: TAMIL NADU – Millet Cafés

In cities like Chennai and Coimbatore, millet cafés are gaining popularity, offering traditional dishes like ragi dosa, bajra upma and millet biryani. Entrepreneurs have collaborated with rural FPOs for sourcing, ensuring farm-to-fork traceability and creating premium markets for millet farmers.

Case Study 3: Export Boom in Karnataka

Karnataka has become a hub for millet exports, especially foxtail and barnyard millets. With government support, farmers in the state are now tapping into global markets in Europe and North America.

Private companies are partnering with FPOs to ensure quality control, certification and logistics.

Recommendations for Strengthening the Millet Ecosystem

To fully realize the potential of Shree Anna, coordinated efforts are required across multiple levels.

For Farmers: Capacity building on best millet cultivation practices

• Access to quality seeds and organic inputs

• Support to form or join FPOs for better collective bargaining

For Entrepreneurs: Innovation in product design, packaging and branding

• Leverage digital platforms and e-commerce to reach health-conscious consumers

• Collaborate with culinary influencers and chefs to create awareness

For Policymakers: Invest in rural processing units and cold storage infrastructure

• Provide MSP (Minimum Support Price) for key millet varieties

• Integrate millets into more government nutrition programs like ICDS and mid-day meals

• Promote millet-based school breakfasts to improve child nutrition and create steady demand

For Academia and R&D: Encourage research into high-yielding, climate-resilient millet varieties

• Study the long-term health impacts of regular millet consumption

• Develop millet-based functional foods and nutraceuticals

Vision for the Future

The revival of millets under the banner of Shree Anna is not just an agricultural reform-it's a cultural, environmental and economic movement. With the right ecosystem of policy, innovation and consumer awareness, India has the opportunity to Become a global leader in millet production and exports, Enhance nutritional security for millions of Indians, Drive climate-resilient and sustainable farming, Create rural jobs and revive traditional food systems, By reconnecting with these ancient grains, India is not only reclaiming its food heritage but also building a healthier and more sustainable future for generations to come.

Conclusion

Millets hold immense promise for building a healthier, more sustainable and inclusive future. As nutrient-rich grains, they offer a powerful solution to address malnutrition and lifestyle disorders across diverse populations. Their climate-resilient nature makes them ideal for cultivation in droughtprone and resource-poor regions, contributing to sustainable agriculture. The growing market demand, both domestically and internationally, presents vast opportunities for entrepreneurship, innovation and value addition. Millets also play a crucial role in empowering women and smallholder farmers by creating local livelihoods and promoting rural food security. With continued support from policymakers, researchers and consumers, India can position itself as a global leader in millet production and marketing, successfully blending traditional wisdom with modern development goals.

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The Ethnomedicinal Significance of Lichens: A Review of Traditional Uses and Potential for Novel Drug Discovery

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Introduction

Lichens, symbiotic associations between fungi and algae or cyanobacteria, have been utilized for centuries in traditional medicine across diverse cultures worldwide. This paper reviews the ethnomedicinal uses of lichens, highlighting their applications in treating a wide range of ailments, from skin conditions and respiratory problems to digestive disorders and even cancer. We examine the bioactive compounds responsible for these therapeutic properties, drawing on existing scientific literature to corroborate traditional claims and explore the potential for novel drug discovery. Furthermore, we discuss the importance of preserving traditional knowledge surrounding lichens and the need for sustainable harvesting practices to safeguard these valuable resources for future generations.

Lichens, often overlooked in their unassuming presence on rocks, trees and soil, represent a remarkable example of symbiosis. This intimate partnership between a fungus (the mycobiont) and an alga or cyanobacterium (the photobiont) gives rise to a unique organism with a diverse array of morphological and chemical properties. For millennia, humans have recognized and utilized these properties, incorporating lichens into their traditional pharmacopeias. Ethnomedicine, the study of traditional healthcare practices, reveals that lichens have been employed across cultures for a multitude of medicinal purposes, showcasing their potential as a source of valuable bioactive compounds. This review aims to synthesize existing ethnobotanical knowledge regarding the medicinal uses of lichens, analyse the scientific evidence supporting these applications and discuss the future prospects of lichen-derived pharmaceuticals.

Traditional Ethnomedicinal Uses of Lichens:

The ethnomedicinal applications of lichens are widespread and varied, reflecting the diverse chemical compositions and geographical distributions of lichen species. Here, we highlight some prominent examples:

• **Skin Conditions:** Perhaps the most prevalent use of lichens in traditional medicine is for treating skin ailments. Species like *Usnea barbata* (Old Man's Beard), known for its usnic acid content, have been traditionally used as wound dressings, antiseptics, and treatments for fungal infections and eczema. Similarly, Parmelia species have been used topically to alleviate skin irritations and promote healing.

- **Respiratory Ailments:** Lichens have been employed to address respiratory problems like coughs, bronchitis and asthma. *Lobaria pulmonaria* (Lungwort), aptly named for its perceived resemblance to lung tissue, has been traditionally used as an expectorant and antitussive. Other lichens, such as *Cetraria islandica* (Iceland Moss), possess demulcent properties that soothe irritated mucous membranes in the respiratory tract.
- **Digestive Disorders:** Lichens have also been utilized to alleviate digestive issues like diarrhea, stomach ulcers and intestinal parasites. *Cetraria islandica,* due to its high polysaccharide content, has been used as a mild laxative and to protect the gastric mucosa. Certain lichen species, such as *Cladonia rangiferina* (Reindeer Moss), are consumed as food sources and believed to aid digestion.
- **Antipyretic and Analgesic Properties:** Some traditional uses suggest that lichens possess antipyretic (fever-reducing) and analgesic (pain-relieving) properties. While specific mechanisms are not always well-understood, certain lichen compounds, such as depsides and depsidones, are known to exhibit anti-inflammatory activities that could contribute to these effects.
- **Other Applications:** Beyond the above, lichens have been traditionally used for a range of other ailments, including tuberculosis, cancer, diabetes and as diuretics and emetics. However, further research is needed to validate these less common applications and to understand the underlying mechanisms of action.

Bioactive Compounds and Their Potential Therapeutic Activities

The therapeutic potential of lichens stems from their diverse array of secondary metabolites, including:

- **Usnic Acid:** This dibenzofuran derivative is perhaps the most well-known lichen compound, recognized for its potent antimicrobial, antiviral, anti-inflammatory and anticancer properties. Usnic acid has been incorporated into various topical products for treating skin infections and promoting wound healing.
- **Depsides and Depsidones:** These phenolic compounds are abundant in many lichen species and exhibit a range of biological activities, including antioxidant, anti-inflammatory, anti-microbial and cytotoxic effects. Examples include atranorin, physodic acid and salazinic acid.
- **Polysaccharides:** Lichens contain various polysaccharides, such as lichenin and is lichenin, which possess imm-unomodulatory, antitumor and antiviral properties. These polysaccharides can stimulate the immune system, inhibit tumour growth and interfere with viral replication.
- **Pulvinic Acid Derivatives:** These pigments contribute to the coloration of many lichen species and exhibit anti-oxidant, anti-inflammatory and neuro-protective activities.

Scientific Validation and Drug Discovery Potential

While traditional uses provide valuable leads, rigorous scientific research is crucial to validate the efficacy and safety of lichen-derived medicines. Numerous studies have investigated the biological activities of lichen extracts and isolated compounds, providing evidence for their potential pharmaceutical applications.

- **Antimicrobial Activity:** Studies have demonstrated the effectiveness of lichen extracts against a wide range of bacteria, fungi and viruses, including antibiotic-resistant strains. This suggests that lichens could provide a source of novel antimicrobial agents to combat emerging infectious diseases.

• **Anticancer Activity:** Research has shown that certain lichen compounds, such as usnic acid and physodic acid, exhibit cytotoxic effects against various cancer cell lines. These compounds may induce apoptosis, inhibit tumor growth and prevent metastasis.

• **Anti-inflammatory Activity:** Lichens contain compounds that can suppress inflammation by inhibiting the production of inflammatory mediators, such as cytokines and prostaglandins. This suggests that lichens could be useful in treating inflammatory conditions like arthritis and inflammatory bowel disease.

• **Neuroprotective Activity:** Some lichen compounds have been shown to protect neurons from oxidative stress and excitotoxicity, suggesting their potential in preventing or treating neurodegenerative diseases like Alzheimer's and Parkinson's.

Challenges and Future Directions

Despite the promising potential of lichens in medicine, several challenges need to be addressed:

• **Sustainable Harvesting:** Lichens are slow-growing organisms and are vulnerable to over-harvesting. Sustainable harvesting practices are crucial to ensure the long-term availability of these resources. Strategies include controlled harvesting quotas, lichen farming and biotechnological production of lichen compounds.

• **Identification and Standardization:** Accurate identification of lichen species is essential, as different species may have varying chemical compositions and medicinal properties. Standardization of lichen extracts and isolated compounds is also necessary to ensure consistent therapeutic effects.

• **Bioavailability and Toxicity:** The bioavailability of lichen compounds can be limited due to their poor solubility and absorption. Furthermore, some lichen compounds may exhibit toxicity at high doses. Research is needed to optimize the delivery and minimize the toxicity of these compounds.

• **Clinical Trials:** While preclinical studies have demonstrated the potential of lichen-derived medicines, further clinical trials are needed to confirm their efficacy and safety in humans.

Conclusion

Lichens represent a rich source of bioactive compounds with significant potential for drug discovery. Their ethnomedicinal uses highlight the long-standing recognition of their therapeutic properties by diverse cultures worldwide. By combining traditional knowledge with modern scientific research, we can unlock the full potential of lichens as a source of novel medicines for treating a wide range of diseases. However, it is crucial to prioritize sustainable harvesting practices and to conduct rigorous clinical trials to ensure the safety and efficacy of lichen-derived pharmaceuticals. By embracing a holistic approach that integrates traditional knowledge, scientific innovation and environmental stewardship, we can harness the power of lichens to improve human health while preserving these valuable resources for future generations.

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The Science behind Seed Treatment for Vegetable Crops

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Introduction

Seed treatment is a fundamental agricultural practice aimed at enhancing seed performance, protecting against diseases and pests and ensuring better crop establishment. It involves applying various physical, chemical and biological treatments to seeds before planting. For vegetable crops, where high germination rates and uniform plant stands are crucial, seed treatment plays a vital role in improving productivity and sustainability.

Importance of Seed Treatment

Vegetable crops are highly susceptible to seed-borne and soil-borne pathogens, insect pests, and environmental stresses. Seed treatment offers several benefits, including:

- **Enhanced Germination:** Treated seeds exhibit higher and more uniform germination rates.
- **Disease Prevention:** Protects against fungal, bacterial and viral infections.
- Insect and Pest Control: Shields seeds from soil-borne insects that may damage seedlings.
- **Improved Seed Vigor:** Strengthens seedlings, making them more resilient to environmental stresses.
- **Reduction in Chemical Use:** Minimizes the need for pesticides during later growth stages.

Types of Seed Treatment

Seed treatment methods are classified into three main categories:

Physical Seed Treatment

Physical methods use non-chemical techniques to enhance seed health and eliminate pathogens. Common physical treatments include:

- **Hot Water Treatment:** Seeds are soaked in water at 50-55°C for 10-30 minutes to kill pathogens.
- **Solarization:** Seeds are exposed to direct sunlight to reduce microbial contamination.
- **Radiation Treatment:** Gamma rays or UV light are used to sterilize seeds and improve disease resistance.
- **Aerated Steam Treatment:** Exposing seeds to steam at controlled temperatures to kill pathogens.

Chemical Seed Treatment

Chemical treatment involves applying fungicides, insecticides and growth regulators to seeds to protect against diseases and pests. Common chemicals used include:

- **Fungicides:** Captan, Thiram, Carbendazim, Metalaxyl to prevent fungal infections.
- **Insecticides:** Imidacloprid, Thiamethoxam to protect against soil-borne insect pests.
- **Growth Regulators:** Gibberellic acid,

cytokinins to enhance seed germination and seedling vigor.

• **Nematicides:** Used to control nematodes that attack root systems.

Biological Seed Treatment

Biological seed treatment involves the use of beneficial microorganisms and organic compounds to improve seed health naturally. These treatments offer a sustainable and eco-friendly alternative to chemicals.

• **Rhizobium Inoculation:** Enhances nitrogen fixation in leguminous vegetable crops.

• **Trichoderma-Based Treatment:** Protects against fungal diseases.

• **PGPR (Plant Growth-Promoting Rhizobacteria):** Stimulates root growth and nutrient uptake.

• **Mycorrhizal Fungi:** Improves phosphorus absorption and enhances stress tolerance.

• **Neem-Based and Botanical Extracts:** Provide natural protection against insects and fungal pathogens.

Methods of Seed Treatment

Different methods are used to apply seed treatments, depending on the type of treatment and crop requirements.

Seed Coating

A uniform layer of protective material containing fungicides, insecticides, or biological agents is applied to seeds. This method ensures even distribution and improved handling.

Seed Pelleting

Seeds are enclosed in a pelletized material containing nutrients and bioagents. This enhances seed size, making them easier to plant and improving seedling emergence.

Slurry Treatment

Seeds are mixed with a liquid suspension of fungicides or insecticides before planting. This provides immediate protection against soil-borne threats.

Soaking Method

Seeds are soaked in chemical, biological, or nutrient-rich solutions for a specific duration before planting to enhance germination and seedling vigor.

Benefits of Seed Treatment

1. Protection Against Pathogens: Reduces early-season disease outbreaks.

2. Improved Germination Rates: Ensures faster and more uniform seedling emergence

3. Enhanced Nutrient Absorption: Biofertilizers and microbial treatments promote better root development.

4. Cost-Effective Pest Management: Reduces reliance on pesticides and fungicides in later growth stages.

5. Eco-Friendly and Sustainable: Biological treatments minimize environmental impact compared to chemical treatments.

6. Increased Yield and Productivity: Stronger plants lead to better harvests.

Challenges in Seed Treatment

Despite its advantages, seed treatment comes with certain challenges:

• **Overuse of Chemicals:** Can lead to phytotoxicity, affecting seed viability.

• **Resistance Development:** Excessive chemical use may cause pests and pathogens to develop resistance.

• **Storage Limitations:** Treated seeds require proper storage conditions to maintain effectiveness.

• **Application Precision:** Incorrect treatment methods can reduce seed efficacy and lead to poor germination.

Future Trends in Seed Treatment

With advancements in agricultural research, innovative seed treatment methods are emerging:

• **Nanotechnology-Based Treatments:** Enhances seed coating efficiency and pathogen resistance.

• **Bioengineered Microbial Inoculants:** Genetically modified bacteria and fungi to improve seed health.

• **Advanced Seed Priming Techniques:** Improves seedling establishment and stress tolerance.

- **Smart Coatings:** Controlled release of nutrients and protective agents for better plant development.

Conclusion

Seed treatment plays a crucial role in enhancing vegetable crop production by improving seed health, germination rates, and resistance to pests and diseases. With the increasing focus on sustainable agriculture, adopting biological and eco-friendly seed treatment methods will be key to ensuring long-term productivity and environmental conservation. By integrating scientific advancements with best agricultural practices, vegetable growers can optimize their yields while reducing chemical dependency, leading to healthier crops and a more sustainable future for farming.

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Effective Nutrient Combination of Spinach Beet Cultivation

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Introduction

Spinach beet (*Beta vulgaris var. bengalensis*; 2n=2x=18) is the most popular vegetable crop grown in India and other parts of the world as leafy vegetable. It belongs to the family Chenopodiaceae. It is also known as Indian spinach, Beet leaf in English and Palak in Hindi and is originated from Indo-Chinese region (Nath, 1976). Spinach beet is rich in vitamins especially vitamin A (97701 IU) and othervitamins like Ascorbic acid (70 mg 100 g^{-1}), Riboflavin, Thiamine. Minerals like Iron and Calcium (380 mg 100 g^{-1}), Folic acid and some amounts of Nicotinic acid, Pyridoxine, Antioxidants as Carotene, Flavones, Indoles and Isothiocyanates, essential amino acids etc. Hence, it is called "Mines of Minerals" (Thamburaj and Singh, 2015).

In recent years, as the consumers are becoming more aware about the use of chemical free vegetables particularly leafy vegetables. Hence, it becomes theneed to sustain the production level with minimum or no use of chemicals. Traditional reliance on chemical fertilizers has raised concerns regarding soil health degradation, environmental sustainability and the accumulation of nitrates in leafy vegetables. In response, Studies have demonstrated that integrated nutrient management (INM), which combines organic manures, inorganic fertilizers, and biofertilizers, significantly enhances the growth, yield and quality of palak. For instance, research conducted by Sharma *et al.*, (2023) indicated that the application of 50% recommended dose of fertilizers (RDF) along with organic manures and biofertilizers resulted in superior plant height, leaf number, and overall yield compared to the use of inorganic fertilizers alone. Similarly, Choudhary *et al*., (2024) reported that INM practices not only improved yield but also enhanced the nutritional profile of palak leaves, contributing to better health outcomes for consumers.

Many farmers primarily use urea as fertilizer, often exceeding recommended amounts, due to lack of awareness in integrated nutrient management. This practice can lead to poor yields and soil health issues. Excessive nitrogen application has been linked to increased nitrate levels in spinach beet leaves without significant yield improvements (Custic *et al.*, 1994), highlighting the need for balanced fertilization strategies. Reducing reliance on inorganic fertilizers is crucial for sustainable agriculture. Integrating unconventional fertilizers, such as biofertilizers, can enhance soil fertility, improve crop productivity and minimize environmental pollution. Keeping this fact in view, A Study has been conducted to find out the effective combination of nutrient application on growth andyield of spinach beet.

Material and Methods

A field experiment has been carried out during Rabiseason in the year 2020-21 at College of Horticulture, Sri Konda Laxman Telangana Horticultural University, Rajendranagar, Hyderabad. The experimental site is situated at an altitude of 536 m above mean sea level on 78°.40' East longitude and 17°.32' North latitude. The experiment plot was ploughed, harrowed with disc to bring it to fine tilth and perfectly levelled divided into plots. The seeds were sown at a spacing of 30 cm between rows and 10 cm within the row followed by Irrigation. A total of three cuttings were taken. The first cutting was done at 30 days after sowing and the subsequent cuttings were made at 15 days interval. Five plants in each treatment and replications were randomly selected and tagged of each replication in each treatment for recording the observations for growth, yield and quality parameters.

A total of ten integrated treatments consisting of inorganic nutrients (75%, 50% and 25% NPK kg/ha), biofertilizers (Azotobacter Phosphorous Solubilizing Bacteria (PSB), Potassium Solubilizing Bacteria (PSB), Arka Microbial Consortium (AMC) with three replications were carried out to know the effective combination of nutrient application on morphological parameters like plant height (cm), leaf length (cm), leaf width (cm) and length of leaf petiole (cm). yield and quality parameters like number of leaves, leaf weight (g), leaf yield per plant (g) and leaf yield (q ha^{-1}). Quality parameters like moisture content (%), shelf life (No. of days), vitamin-C (mg 100 g^{-1}), carotene content (mg 100 g^{-1}), physiological loss in weight (%) were worked out.

Results and Discussion

Results revealed that maximum growth, yield and quality was obtained in 50% Recommended Dose of Fertilizers (NPK kg/ ha), 50% Biofertilizers (Arka Microbial Consortium + Potassium Solubilizing Bacteria) along with Arka vegetable special (micronutrient spray). The increment of growth, yield and quality might be due to application of inorganic nutrients and biofertilizers i.e., Azotobacter, PSB, KSB and AMC which have enhanced the availability of N and P in soil as major plant nutrients. The yield improvement may be attributed to higher yield attributing components such as increased vegetative and yield parameters which were positively affected by the foliar application of micronutrients as reported by Diana and Nehru (2014).

Conclusion

The study underscores the efficacy of integrated nutrient management (INM) in enhancing the growth, yield and quality of spinach beet (*Beta vulgaris var. bengalensis*). The optimal treatment-comprising 50% recommended dose of inorganic fertilizers (NPK), 50% biofertilizers (Arka Microbial Consortium and Potassium Solubilizing Bacteria) and foliar application of Arka Vegetable Special-demonstrated significant improvements in plant height, leaf dimensions, leaf number, and overall yield. This integrated approach not only optimized nutrient availability but also improved soil health and reduced reliance on chemical fertilizers. The findings advocate for the adoption of INM practices, combining reduced chemical inputs with biofertilizers and micronutrients, to achieve sustainable and high-quality spinach beet production.

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Agroforestry in India: Green Wealth for Farmers and Environment

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Introduction

The National Agroforestry Policy (2014) defines agroforestry as an integrated land-use system that combines trees and shrubs with agricultural crops and rural landscapes, with or without livestock, to enhance productivity, profitability, biodiversity and ecosystem sustainability. In India, the total forest and agroforestry land cover approximately 69.79 million hectares (FSI, 2013) and 25 million hectares (Dhanya *et al.*, 2013), respectively, out of a total geographical area of 305.60 million hectares. Agroforestry significantly contributes to carbon sequestration, with an estimated carbon stock of 532.5 million tons. Additionally, scattered trees on farmlands and field bunds further enhance environmental benefits. Despite the immense potential of agroforestry in India, its adoption remains limited due to several challenges. Key barriers include inadequate market infrastructure, a shortage of high-quality planting material, complexities in wood transportation and processing, insufficient research, and restrictive policies governing tree cultivation (Sharma *et al.*, 2017). However, agroforestry presents significant opportunities to improve both environmental sustainability and economic viability, offering multiple benefits such as food, fodder, timber, fuel wood and fiber to support rural livelihoods and socioeconomic development (Bijalwan *et al.*, 2011).

Addressing climate change is a critical global concern, and one effective strategy is to increase forest and tree cover through agroforestry. This approach enhances the resilience of agricultural systems, particularly for farmers relying on monoculture practices (Dhyani, 2014). Agroforestry meets the growing demand for plywood, high-quality raw materials for paper and pulp industries, construction timber, protein-rich fodder for livestock and fuelwood for daily household consumption, while also contributing to pollution reduction and environmental conservation (NRCAF, 2013).

Agroforestry systems are particularly prevalent in arid and semi-arid regions of India, where native tree species such as *Leucaena spp*., *Prosopis spp*., *Acacia spp*. and *Ficus spp*. are commonly integrated into silvopastoral systems. These systems, which combine tree plantations with pasture management, are widely practiced by local cultivators to optimize land productivity and sustainability (Viswanath *et al.*, 2018).

Types of agroforestry systems

1) Agrisilvicultural Systems: These systems combine trees and crops, often involving alley cropping (planting crops between rows of trees) or home gardens.

2) Silvopastoral Systems: These systems integrate trees with livestock and forage production, often involving grazing livestock in wooded rangelands or incorporating trees in pastures for shade and timber.

3) Agrosilvopastoral Systems: These systems combine all three elements: trees, crops and livestock.

Benefits of Agroforestry

A. Environmental Benefits

1) Soil Conservation and Fertility Improvement: Tree roots bind the soil, preventing erosion and improving its structure. Leaf litter from trees enriches the soil with organic matter, boosting fertility.

2) Carbon Sequestration: Agroforestry systems act as carbon sinks, absorbing and storing carbon dioxide from the atmosphere. This helps mitigate climate change.

3) Biodiversity Enhancement: Trees provide habitat for birds, insects and other wildlife, contributing to biodiversity conservation.

B. Economic Benefits for Farmers

1) Diversified Income Sources: Farmers can earn from multiple products, such as fruits, nuts, timber, and medicinal plants, reducing their reliance on a single crop.

2) Increased Productivity: Studies have shown that agroforestry systems are often more productive than conventional farming due to better resource use and soil health

3) Resilience to Climate Extremes: Agroforestry can make farms more resilient to droughts, floods and other climate-related challenges by improving microclimates and water retention.

C. Social and Community Benefits

1) Employment Generation: Agroforestry creates jobs in activities such as nursery management, tree planting, harvesting and product processing.

2) Strengthening Rural Communities: and knowledge-sharing among farmers, fostering stronger community ties.

Agroforestry Success Stories in India

1) Shri Jagdish Prasad, Palampur, Kangra, Himachal Pradesh

Shri Prasad adopted a block plantation system for Kagzi lime with a planting density of approximately 10 trees per acre, yielding an annual income of around ₹ 5,000. Additionally, he strategically planted Morus alba (mulberry) saplings along the field boundaries. By pollarding these trees three times a year at a height of five feet, he was able to obtain high-quality tree fodder, while the tree boles served as durable fencing materials.

Furthermore, Shri Prasad introduced Setaria anceps, a fast-growing, high-yielding grass, between the rows of fruit trees and along the boundaries adjacent to the mulberry plantation. This approach ensured year-round availability of green fodder for his livestock, significantly reducing reliance on dry fodder.

Through the implementation of the silvi-horti-pastoral agroforestry system, Shri Prasad has successfully enhanced his farm's productivity, generating an additional annual income of ₹ 20,000.

2) Shri Satyam Singh, Umra, Sultanpur, Uttar Pradesh

Shri Singh established a teak plantation along the boundary of his farm in 2008 and is currently generating an annual profit of approximately ₹ 1.5 lakh from timber sales. According to him, the adoption of the Agri-silviculture system (Teak + Paddy-Wheat) has resulted in a 25% increase in income compared to traditional mono-cropping practices.

3) Shri Jagjit Singh, Rupnagar, Punjab

Shri Singh has implemented a poplar-based agroforestry system on his 9-acre farm, yielding approximately 550 quintals of timber per acre. This practice generates an annual revenue exceeding ₹ 5,00,000.

In 2022, he expanded his venture by establishing a poplar nursery, where he sells poplar ETPs at ₹ 20–30 per unit, earning an additional ₹ 1,00,000 per year.

According to Shri Singh, the poplar-based agroforestry system is one of the most effective land-use interventions, contributing to both soil health improvement and income security for farmers.

4) Shri Tejram R. Zode, Umred, Nagpur, Maharashtra

Under the technical guidance of the AICRP Centre, Nagpur, Shri Zade has successfully implemented a bamboo plantation in a block plantation mode (3.6m x 2.5m) with a density of 1,111 plants per hectare. This initiative generates an annual income of ₹ 90,000 through the sale of bamboo poles to essence stick manufacturing industries.

Additionally, he has adopted a bamboo + turmeric agroforestry system on another plot, utilizing spacings of 5.0m x 2.5m and 6.0m x 2.5m. This integrated system provides him with a net annual return exceeding ₹ 3,00,000.

To further expand his enterprise, Shri Zade has entered into an agreement with a local essence stick manufacturing industry to establish an "Agro Producer Company" for the sustained supply of bamboo poles to the industry.

Conclusion

Agroforestry is a sustainable land-use system that enhances farm productivity, supports biodiversity and provides economic benefits to farmers. Despite its vast potential, challenges like market access, policy constraints and lack of quality planting material hinder its widespread adoption. However, success stories across India demonstrate how integrating trees with crops and livestock can significantly boost farmers' income while improving soil health and resilience to climate change. With supportive policies, research, and infrastructure, agroforestry can play a crucial role in ensuring ecological balance and rural prosperity in India.

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For the welfare of the Farmer's, the society "Society for Advancement in Agriculture, Horticulture and Allied Sectors" willing to publish E-magazine in the name of "Krishi Udyan Darpan E-Magazine (Hindi) / **Krishi Udyan Darpan** E-Magazine (English**, Innovative Sustainable Farming**.)**, which covers across India.**

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13. Introduction must present main idea of article. It should be well explained but must be limited to the topic.
14. Avoid the **Repetitions** of word's, sentences and Headings.
15. The main body of an article may include multiple paragraphs relevant to topic. Add brief subheads at appropriate places. It should be informative and completely self-explanatory.
16. Submitted manuscript are only running article and contains the field of Agriculture, Horticulture and Allied sectors.
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ABOUT THE SOCIETY

Father of Nation Mahatma Gandhi's concept of rural development meant self-reliance, and least dependence on outsiders. India is an agrarian country and about 65% of our population lives in rural areas. But unfortunately, most of us do not have any idea about the extent of poverty and the real conditions of rural India.

With the purpose of serving the agricultural fraternity and farming community the Society for Advancement in Agriculture, Horticulture and Allied Sectors (SAAHAS) was founded in 2020 (under Society Registration Act, 1860). Among multifarious ways of serving farming community we are involved in training of the farmers by organising technology dissemination programmes in villages, guiding them to adopt good agricultural practices involving planned crop management. It helps in reducing farm base losses and motivating them to become farmer level entrepreneur rather than a simple producer. It involves initiating skill based knowledge to the student of agriculture, horticulture and allied sectors to encourage them to serve the farmers in the best possible ways.

SAAHAS calls us to look into the genuine problems of farmers and address those issues for their betterment in the arena of Agriculture, horticulture and allied sectors. Besides agriculture, horticultural crop production has been given a major focus by Govt. of India in future crop diversification, improving livelihood through doubling farmers' income, economic opportunities through export and job opportunities. While good beginning is made, much is to be achieved in different areas in agro-horticulture sector.

Apart from that, SAAHAS helps developing the culture to involve more number of women in farming, processing of crops and value addition thereof for higher returns in terms of total income. SAAHAS eagerly involves with the farmers and agriculture entrepreneur to motivate them for introducing hi-tech farming, which includes growing of high value horticultural crops in hydroponics, aeroponics, polyhouse, net house and greenhouse. The society has geared up its activities to take up the challenges of biotic and abiotic stresses, emerging needs of quality seeds and planting material and reducing cost of production.

There are several government and non-government organisations intended of farmer's welfare; still there is dire need for more involvement and attachment with the farmers. Our society's noble initiative can ensure diminishing of the persistent gap between agro-technocrats, scientists with the needy farmers. We not only ensure that the farmers choose right variety of right crop, better nutrient management through diagnosis recommended system and pest diagnosis but we also help them to sale their produce at premium rates. There is a major issue of chemical residues in food, soil and ecology which is also a big concern of the century. The Society also aims to motivate the farmers either for minimal use of chemical inputs or total adoption of organic farming. Consultancy, training, awareness programs, national and international seminars and symposia and technical services are the prime activities of the SAAHAS.

Society for advancement in Agriculture, Horticulture and Allied Sectors publishes peer reviewed scientific journal, 'Journal of Applied Agriculture and Life Sciences (JAALS)', biannually since January 2020 focusing on articles, research papers and short communications of both basic and applied aspect of original research in all branches of Agriculture, horticulture and other allied sciences. To apprise the scientists and all those who are working in the field of Agriculture, horticulture and allied sectors about recent scientific advancement is the aim of the Journal.