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HANDLING AND POST HARVEST TECHNOLOGY OF HORTICULTURAL CROP

Introduction

All harvested horticultural foods are living biological organism, having a respiratory system similar to that of humans. They continue to respire after harvest and thus change their characteristics depending on produce handling and storage treatment. Horticultural crops have great challenges from the standpoint of postharvest loss both in terms of quantity and quality between harvesting and final consumption. Postharvest technologies constitute an interdisciplinary science and technologies (chemical engineering, Food engineering and technology, microbiology, etc.) applied to agricultural commodities after harvest for purpose of preservation, conservation, quality control/enhancement, processing, packaging, storage, distribution, marketing and utilization to meet the food and nutritional requirement of consumers in relation to their needs. The main objectives of handling strategies are to take care of quality (appearance, texture, flavour and nutritive value) maintain food safety and to scale back losses between harvest and consumption. Fresh fruits and vegetables play a very significant role in human nutrition, especially as sources of vitamins (Vitamin C, Vitamin A, Vitamin B6, thiamine, niacin), minerals, and dietary fiber. Other constituents that may lower risk of cancer and other diseases include flavonoids, carotenoids, polyphenols and other phytonutrients. Postharvest losses in nutritional quality, particularly Vitamin C content, can be substantial and are enhanced by physical damage, extended storage duration, high temperatures, low relative humidity, and chilling injury of chilling-sensitive commodities.

Post Harvest Strategies

Pre-harvest factors such as production location, planting date, soil type, irrigation, shading and nutrient largely affect post-harvest quality of produce.soil type, mulching, fertilization, micro agro-climatic conditions of the soil and other cultural practice influences the water and nutrient content of the plant which can also affect compositional attributes such as appearance, texture, taste, and aroma of the harvested plant parts. The report also stated that climatic condition especially temperature, humidity and light intensity has strong effect on the nutritional quality of food products. Heavy pruning diminishes leaf area, whole tree photosynthesis and translocation of photosynthates of fruits and root crops, increasing the root/shoot ratio and favouring vegetative growth. Field management practices such as pest control, soil fertility and water management are of great importance in achieving good quality attributes in size, colour, flavour, texture and nutritional value of vegetables.

Post Harvest Handling of Fruits and Vegetables

Sanitizing and Cleaning

The removal of dirt and stones can be done manually or through a sieve. Some fruits can be washed, brushed, or wiped with a soft cloth. Cleaning is required to clean fruits that have latex stains due to crop injuries, such as in mango, papaya, and breadfruit. Fruits and vegetables can get contaminated during harvest operation and thus requires good sanitation system particularly during all pre and postharvest operations to eliminate sources of infection and reduce levels of fruit contamination.

Harvest Handling

Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept shaded in the field. Handle produce gently. Crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms as well. Postharvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400% by a single bad bruise on an apple, and skinned potatoes may lose three to four times as much weight as non-skinned potatoes.

Postharvest and Storage Considerations

Pre-Cooling

Pre-cooling is the first step in good temperature management. The field heat of a freshly harvested crop—heat the product holds from the sun and ambient temperature—is usually high, and should be removed as quickly as possible before shipping, processing, or storage. Refrigerated trucks are not designed to cool fresh commodities but only maintain the temperature of pre-cooled produce.

There are five principal methods of pre-cooling fresh produce

Room Cooling

Produce is placed in an insulated room equipped with refrigeration units. This method can be used with most commodities, but is slow compared with other options. A room used only to store previously cooled produce requires a relatively small refrigeration unit. However, if it is used to cool produce, a larger unit is needed.

Forced-air Cooling

Fans are used in conjunction with a cooling room to pull cool air through packages of produce. Although the cooling rate depends on the air temperature and the rate of air flow, this method is usually 75–90% faster than room cooling.

Hydro Cooling

Hydrocooling essentially is the utilization of chilled or cold water for lowering the temperature of a product in bulk or smaller containers before further packing. Hydrocooling is achieved by flooding, spraying, or immersing the product in/with chilled water. There are several different hydrocooler designs in operation commercially. Hydrocooling methods differ in their cooling rates and overall process efficiencies.

Vacuum Cooling

In the vacuum cooling process the pressure in the vacuum chamber is reduced from atmospheric to about

20 mbar and, during this time, evaporation is slow and relatively little cooling takes place, i.e., temperature of the produce remains constant until saturation pressure at this temperature is reached. At approximately this pressure the `flash point' occurs; this is the point where the water in the produce begins to vaporize, i.e., produce begins to lose moisture and cool rapidly.

Relative Humidity: The rate of loss of water from fruit, vegetables and flowers depends upon the vapor pressure deficit between the surrounding ambient air, which is influenced by temperature and relative humidity. The rate of deterioration is a combined factor of temperature and relative humidity and affects the produce in following manner:

Fruits and vegetables	Temperature (C)	% Oxygen	% Carbon dioxide
Apple	0-5	2-3	1-2
Bananas	12-15	2-5	2-5
Cantaloupe	3-7	3-5	10-15
Kiwifruit	0-5	2	5
Lettuce	0-5	2-5	0
Nuts and dried fruits	0-25	0-1	0-100
Strawberry	0-5	10	15-20

Evaporative Cooling

Evaporative cooling is an inexpensive and effective method of lowering produce temperature. It is most effective in areas where humidity is low. Dry air is drawn through moist padding or a fine mist of water, then through vented containers of produce. As water changes from liquid to vapor, it absorbs heat from the air, thereby lowering the produce temperature. The incoming air should be less than 65 percent relative humidity for effective evaporative cooling. It will only reduce temperature, 10-15°F. This method would be suitable for warm-season crops requiring warmer storage temperatures (45-55°F), such as tomatoes, peppers, cucumbers, or eggplant.

Management of Temperature and Humidity

Temperature

Every increase of 100C temperature above optimum increases the deterioration by two times.

Exposure to undesirable temperature results in many physiological disorders like; freezing injury, chilling injury and heat injury etc.

Temperature influence growth rate of fungal spores and other pathogens.

It affects the respiration and transpiration rate of produce.

Low Temperature & High Relative Humidity -- Low deterioration

Low Temperature & Low Relative Humidity -- Moderate deterioration

High Temperature & High Relative Humidity -- High deterioration

High Temperature & Low Humidity -- Very high deterioration

Washing, Cleaning and Trimming

Simple postharvest operation such as cleaning, washing and trimming makes produce very fresh after harvest and make convenient for the produce to sales in the market. Preparation for the fresh market starts with dumping onto packinghouse feeding lines. Dumping may be dry or in water (Fig. 20 and 21). In both cases it is important to have drop decelerators to minimize injury as well as control the flow of product. Water dipping of produces causes less bruising and can be used to move free-floating fruits. However, not all products tolerate wetting. A product with a specific density lower than water will float, but for the produce which sinks, salt (NaCl) is diluted in the water to improve floatation.

Sorting, Grading and Sizing

Sorting is done by hand to remove the fruits which are unsuitable to market or storage due to damage by insects, diseases, or mechanical injuries. The remainder crop product is separated into two or more grades on the basis of the surface color, shape, or visible defects. For e.g., in an apple packing house in India 3 grades viz. Extra Fancy, Fancy and standard may be packed for marketing. The fourth "cull" grade is meant for processing. After sorting and grading, sizing is done either by hand or machine. Machine sizers work on two basic principles: weight and diameter. Sizing on the basis of fruit shape and size are most effective for spherical (Oranges, tomato, certain apple cultivars) and elongated (Delicious apples and European pears or of non-uniform shape) commodities.

Packaging

Packaging should be designed to prevent physical damage to produce, and be easy to handle. The American Vegetable Grower magazine's annual product guide is a good source of information about suppliers.

Benefits of Packaging

Packaging serves as an efficient handling unit. It serves as a convenient storage unit. Packaging protects quality and reduces waste.Protects from mechanical damages. Protects against moisture loss.May provide beneficial modified atmosphere.Provides clean produce.May prevent pilferage. Provides service and sales motivation. Reduces cost of transport and marketing.Facilitates use of new modes of transportation.

To assemble the produce into convenient units for handling.To protect the produce during distribution, storage, and marketing.Containment - package contains the product with in it and prevents leakage etc.

Requirement for an Ideal Package

Package should have sufficient mechanical strength to protect the content during handling, transportation,and stacking.Allow rapid cooling of the contents, and/or offer degree of insulation from the external heat/cold.Utilizes the gas barrier (e.g., plastic films) with sufficient permeability to respiratory gases as to avoid any risk of anaerobiosis (ventilation) and any bad odor.It must be easy to assemble, fill and close either by hand or by use of a simple machine.Offer the security for the contents, and /or ease of opening and closing in some marketing situation (e.g., promotional activity).Facilitate easy disposal, Eg. Plastic boxes which nest in each other when empty Collapsible plastic crates, cardboard boxes, fiber or paper or plastic sacks.Package must be readily available.

Storage

"Storage" as now applied to fresh produce is almost automatically assumed to mean the holding of fresh fruit and vegetables under controlled conditions. There are variations in the storage potential of different cultivars of the same crop.They quickly deteriorate because of their fast respiration rates, which cause rapid heat build-up and depletion of their high moisture content. Pulses have a long storage life, provided they are kept dry, and do not present a storage problem as is the case of fresh produce.Some of the factors that affect storage of fruits and vegetables are discussed in details below.

Controlled Atmosphere (CA) storage

It is based, on the principle of maintaining an artificial atmosphere in storage room, which has higher concentration of CO_2 and lower concentration of O_2 than normal atmosphere. This reduces the rate of respiration and thus delays aging. This method of storage is ver y effective when combined with low temperature storage.

Cold storage

These structures are extensively used to store fruits and vegetables for a long period and employ the principle of maintaining a low temperature, which reduces the rate of respiration and thus delays ripening. The respiratory intensity of refrigerated products is directly related to the optimum temperature in the storage room. Lowering the temperature reduces the respiratory rate of the fruit, further slows the rate of biochemical reactions, and improves the shelf life of the product.

Evaporative cool storage

It is the best shortterm storage of fruits and vegetables atfarm level. It helps the farmers to get better re turns for their produce. In this structure, horticult ural crops reduce shriveling and extend their storage life.

Ventilated Storage

Ventilated storage structures have an inflow of air that ensures nominal storage temperature. This air can be naturally expelled or pushed into structures. The simplest system is natural ventilation storage. Forced ventilation, on the other hand, uses an additional fan to speed up heat and gas exchange. Air is extruded through stored crops at a rate of 1013 m/s. Some properties include side vented storage structure (25 - 50 tons capacity), concentric structures, low volume low-cost structures (5 - 10 tons capacity) made of bamboo, Nasik type storage structure.

Conclusions

Storage rooms must be kept clean. Storage facilities should be protected from rodents by keeping the immediate outdoor area clean, and free from trash and weeds. Containers should not be stacked beyond their stacking strength. Temperature should be monitored in the storage room by placing thermometers at a variety of locations. Storing ethylene-sensitive commodities with those that produce ethylene should be avoided. Produce known for emitting strong odors (apples. garlic, onions, turnips. cabbages, potatoes) should not be stored with odor-absorbing commodities. Stored produce should be inspected regularly for signs of injury, water loss, damage and disease. Damaged or diseased produce should be removed to prevent contamination. Postharvest handling is the final stage in the process of producing high quality fresh produce.This document is intended to serve as an introduction to the topic and a resource pointer; the grower is advised to seek out more complete information from Extension and other sources.

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IRRI's Ultra-Low GI High-Protein Rice Revolutionizes Nutrition and Agriculture

Introduction

For billions of people worldwide, rice is a staple meal that forms the foundation of diets in Latin America, Asia and Africa. Conventional rice types, on the other hand, are frequently criticized for having a high glycemic index (GI) and a low protein content, which makes them less appropriate for people with diabetes and those following diets low in protein. The International Rice Research Institute (IRRI) has made history by introducing a new high-protein, ultra-low GI rice variety, paving the way for a healthier substitute for conventional rice.

Uniqueness

1. Low Glycemic Index (GI)

Its glycemic index of 44 is among this rice variety's most noteworthy features. In contrast, the majority of white rice types have GIs ranging from 70 to 90, which indicates that they quickly raise blood sugar levels after eating. Due to its slower rate of glucose absorption and improved glycemic management, this rice's GI of 44 makes it a diabetes-friendly choice. Millets, which are typically advised for diabetics, are nutritionally comparable to rice because of this trait.

2. High Protein Content

With 16% protein, this rice type offers a significant improvement over regular rice, which normally has only 6-8% protein. For those who want to improve muscle growth and repair or who want a balanced diet without totally converting to other grains like millets, the higher protein content makes it a great choice. Those who are protein malnourished, particularly in poor nations.

3. Other Health Benefits

In addition to its high protein content and low GI, this type of rice has further health advantages:

- **Gluten-free:** This makes it appropriate for people with celiac disease or gluten intolerance.
- **Starch modification:** This rice is probably designed to have more resistant starch, which slows down digestion and releases energy for a longer period of time.

Impact on Agriculture and the Market

The introduction of functional rice varieties like this one marks a new era in rice farming. The potential benefits extend beyond just consumers to farmers, policymakers and the agricultural economy.

1. Competition with Millets and Functional Grains

Ragi, barnyard millet and foxtail millet are among the millets that have become more popular because of their excellent nutritional content and low GI. However, this type could fill the gap by providing the same advantages while preserving the flavor, texture and cooking qualities of rice—the staple food of millions of people.

2. Higher Market Demand for Healthier Grains

Increased demand for nutrient-dense foods is a result of greater health consciousness. Potential benefits of this rice variety include:

- Attracting premium pricing in both export and domestic markets.
- Provide farmers with additional chances to grow rice with extra value.
- Support government programs aimed at promoting healthier food options.

3. Adoption and Cultivation Feasibility in India

One of the biggest producers and consumers of rice is India, which offers a sizable market for this invention. The variety may be widely adopted by Indian farmers if it is climate-resilient and has strong yield potential. In areas where diets lack protein, inclusion into nutritional security initiatives may also aid in the fight against malnutrition.

The Future of Biofortified Rice

IRRI's ultra-low GI, high-protein rice is part of a broader movement toward biofortified crops, which aim to address nutritional deficiencies through genetic improvement and advanced breeding techniques. Similar efforts have been seen in:

- **Golden Rice** - rich in Vitamin A
- **Zinc-Enriched Rice** -to combat zinc deficiency
- **Drought-Resistant Rice** - for climate adaptation

As food security and health concerns become more pressing, such nutritionally enhanced rice varieties will play a crucial role in shaping the future of agriculture.

Conclusion

Not just another rice variety, IRRI's most recent creation signifies a move toward more sustainable and healthful eating habits. Both consumers and farmers stand to gain from this rice variety's potential to transform rice consumption habits due to its low glycemic index, high protein content and other health advantages.

If widely adopted, this functional rice could pave the way for a new category of smart staples, making everyday meals both healthier and more nutritious.

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Death in the Valley's Waters: Unravelling the crisis in Kashmir's Fisheries

Introduction

Kashmir, which is often called "paradise on Earth," is famous not only for its beautiful scenery and snow-capped mountains, but also for its huge freshwater resources, which have long supported human and wildlife. Jammu and Kashmir has about 57,000 hectares of water bodies, including 24,000 hectares of lakes, marshes, and reservoirs. It is home to many different types of cold and warm water fish, such as trout, Schizothoracines, and Chinese carps. The valley's fishing industry is based on these bodies of water, which range from the calm Dal Lake to the fast-flowing rivers like Lidder and Jehlum. For generations, this industry has provided a steady source of income, especially for people who are poor.

The fishing industry in Jammu and Kashmir is very important for thousands of families because it provides them with money, food security, and jobs. Even though it only makes up less than 2% of the UTs agricultural economy, it is very important. But now, this traditional and long-lasting way to make money is in danger because of a worrying and growing problem:

Mass Fish Kill. In the past few years, there have been a lot more unexpected, large-scale fish deaths in Kashmir. This has affected farmers, polluted water systems, and made scientists and environmentalists worried. These events are no longer one-time things; they are happening more and more often, which shows that the environment is getting worse day by day.

Fish Kill Incidents in Kashmir:

Several well-known fish deaths in the recent past have made the news and upset farmers and officials. One of the worst things that happened in 2018 was in Langate, Kupwara, where more than 14,000 trout were found dead on a trout farm. Early investigations showed that someone had intentionally put an unknown chemical into the Mawar Nallah, which is the facility's main water source. It looks like the fish died within minutes, and an investigation was ordered.

In the same way, a private fish farm in Heff village, Shopian, lost about 7,000 fish in March 2025. People in the town and on the farm said that someone had poisoned the pond on purpose, maybe because of personal animosity. The authorities are looking into the situation right now, but the family that was affected has had to deal with a lot of pain and money loss.

In the village of Tumlihal in the Pulwama district, a local farmer lost almost all of her fish stock overnight, which is another cause for concern. Once again, the water that ran off of nearby orchards and into the pond was thought to be the source of the problem, possibly because agricultural equipment's were being cleaned in the stream that fed the pond.

In July 2024, there were reports of similar environmental poisoning in Srinagar, when thousands of dead fish were found floating in the Tsoont Koel stream near the Barbar Shah neighbourhood. Officials said that the deaths were caused by a mix of low oxygen levels, pollution from garbage, and high summer temperatures.

Not even natural bodies of water have been spared. In February 2024, more than 3,000 fish died in the Samba district's Mansar Lake. At first, this was confusing, but wildlife experts later explained that fish mistook hailstones for food during a rainstorm, which caused them to eat ice and die from severe internal shock. Similarly large-scale fish deaths were observed in Dal Lake in May 2023 which on analysis by the experts was sought to be brought on by thermal stratification of the lake.

No matter where they came from, these events show how the region's aquatic species are becoming more and more vulnerable.

Image credit: Greater Kashmir

The Indian Express

Understanding the Causes of the Environment:

Intentional poisoning is a big problem, but many fish deaths in Kashmir are caused by different environmental factors, which shows that there are bigger problems with the environment. Eutrophication is one of the main causes. It happens when too many nutrients build up in water bodies, mostly from fertilizers, sewage, and trash. This makes algae grow quickly, which uses up the oxygen in the water and makes it bad for fish. The lakes Dal, Wular, and Nigeen have high levels of nutrients. This is thought to be because of a mix of wastewater from homes, direct disposal of wastes, and runoff from nearby farms.

Another big reason is hypoxia, which is when there isn't enough dissolved oxygen in the water. This is happening more and more during the summer season. When the temperature goes up, oxygen dissolves less well in water. This hurts the fish, especially cold-water fishes like trout. This problem is exacerbated in stagnant or slow-moving water bodies, such as urban streams and ponds. The Tsoont Koel stream in Srinagar is a prime example of how pollution, organic waste, and high temperatures created fatal circumstances for aquatic life.

Pesticide runoff is also becoming an increasingly significant cause of fish mortality. Many orchard owners all over Kashmir use chemical pesticides, which eventually make their way into nearby streams and ponds. Even the act of cleaning spraying equipment in water sources has proven detrimental to fish populations. Furthermore, widespread and frequently illegal sand and gravel mining in trout-rich rivers has damaged breeding sites, increased water turbidity, and disrupted aquatic life cycles, resulting in higher fish mortality and long-term damage to river ecosystems.

Climate change, with its irregular weather patterns, flash floods, hailstorms, and rising temperatures, has exacerbated these difficulties, making Kashmir's aquatic ecosystems more vulnerable and less adaptable to shocks.

Mitigation Strategies: What Can Be Done?

To reduce periodic fish kills and restore balance to aquatic ecosystems, an integrated approach including government agencies, local people, and environmental experts is required. The first stage is to create a comprehensive water quality monitoring system that includes all important lakes, rivers, and fish farms. Regular testing and early warning measures would allow for quick reactions to contamination situations, avoiding large-scale losses.

Furthermore, strict pollution control rules must be enforced, especially around sensitive water bodies. Priority should be given to the construction of suitable sewage treatment plants and the regulation of waste discharge from residential areas as well as tourism-related establishments such as houseboats. Agricultural methods must also be scrutinized. Promoting organic farming near water bodies, limiting the use of toxic pesticides, and enforcing buffer zones between orchards and streams can all help to prevent chemical runoff. Another essential demand is a complete prohibition on unauthorized riverbed mining in trout streams. Government-backed insurance systems and swift reimbursement processes can help fish farmers cope with the financial shocks caused by unexpected fish kills.

Finally, awareness campaigns and capacity-building programs for farmers, orchardists, and local youngsters are critical. Educating communities about how their daily actions affect the environment can develop a sense of shared responsibility and pave the road for more sustainable coexistence with nature.

Conclusion: A Call to Ecological Responsibility.

Kashmir's fishing sector is more than just an economic activity; it is a way of life for people, particularly in rural and economically disadvantaged areas. The current increase in fish kill events, many of which are preventable, demonstrates a worrying disregard for ecological balance and environmental safeguards. The death of thousands of fish in a matter of minutes is more than simply a financial loss; it also indicates a crumbling environment.

Without immediate and sustained measures, these incidences would continue to escalate, endangering not only the livelihoods of fish farmers, but also the biodiversity and viability of Kashmir's freshwater legacy. Protecting these aquatic sources must become a common goal among government agencies, local groups, and residents. The valley, noted for its tranquil lakes and diverse wildlife, must not become a site where lifeless waters convey the story of human neglect and environmental degradation.

Instead, with the correct policies, vigilance, and community participation, Kashmir's waterways may be restored as sanctuaries of life, sustenance, and natural beauty.

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ARTICLE ID: 04

Role of Biostimulants in Enhancing Seed Yield and Quality

Abstract

Biostimulants are an innovative class of substances that promote plant growth and health, leading to improved seed yield and quality. This article explores the types of biostimulants, their mechanisms of action, and their specific roles in enhancing crop performance. Through case studies and research evidence, this article will highlight how biostimulants can serve as a sustainable alternative in agriculture, reducing dependency on synthetic inputs and contributing to food security and environmental sustainability.

Keywords: Sea weed, Humic acid, Seed yield, Seed quality

Introduction

Biostimulants have emerged as an innovative approach in agriculture, offering unique benefits for enhancing crop yield, quality, and resilience. These are biologically derived substances or microorganisms that, when applied to plants or soils, stimulate natural processes to improve nutrient uptake, growth, stress tolerance, and overall plant health. Unlike traditional fertilizers and pesticides, biostimulants do not provide nutrients directly nor act as crop protectants but instead influence plant metabolism and physiological responses, which indirectly support plant growth and productivity. The concept of biostimulants aligns closely with the principles of sustainable agriculture, as they contribute to reduced chemical input usage, enhanced soil fertility, and resilient cropping systems.

In recent years, increasing food demand, coupled with concerns over environmental degradation from conventional agricultural practices, has fueled interest in biostimulants. Biostimulants offer the potential to improve seed yield and quality by optimizing the plant's inherent physiological pathways and reducing dependency on synthetic inputs. Their application can positively impact seed germination rates, seedling vigor, nutrient use efficiency, and even the nutritional profile of crops, making them a valuable tool for achieving high-quality, nutrient-rich food. This is particularly relevant as global agriculture faces challenges such as nutrient-poor soils, climate variability, and the need for sustainable intensification to feed a growing population.

Various types of biostimulants, including plant extracts, amino acids, seaweed extracts, humic substances, and beneficial microbes, act through multiple mechanisms to promote plant growth and productivity.

For instance, amino acids provide building blocks for protein synthesis, while seaweed extracts supply natural growth hormones that enhance plant development. Microbial biostimulants, such as plant growth-promoting rhizobacteria (PGPR) and mycorrhizal fungi, establish beneficial relationships with plants, facilitating nutrient uptake and improving soil structure. This diversity of sources and functions makes biostimulants adaptable across different cropping systems and environmental conditions.

Improving seed yield and quality is essential for agricultural productivity, as seed quality determines not only the crop's growth potential but also its resilience to stresses and its nutritional value. By enhancing various aspects of plant growth and stress tolerance, biostimulants can contribute to higher yields and better-quality seeds, thereby supporting food security and improving the economic value of crops. Additionally, the use of biostimulants promotes sustainable farming practices, as these products often work by enhancing the plant's own abilities rather than introducing external chemical inputs that may negatively impact the environment.

This article explores the role of biostimulants in improving seed yield and quality by examining their types, modes of action, effects on plant growth, and advantages over conventional agricultural inputs. Through this analysis, we aim to understand how biostimulants can contribute to sustainable agricultural systems while supporting the growing need for high-yield, high-quality food production.

Types of Biostimulants and Their Sources

Plant Extracts and Botanical Biostimulants: Plant extracts, often derived from algae, legumes, or other botanicals, contain bioactive compounds such as hormones, enzymes, and vitamins. These extracts have been shown to enhance plant growth by stimulating root development and nutrient uptake (Yakhin et al., 2017).

Amino Acids and Protein Hydrolysates: Amino acids serve as essential building blocks for plant proteins, promoting enzyme synthesis and stress tolerance. Protein hydrolysates, derived from animal or plant sources, improve photosynthesis and nutrient absorption, leading to higher yield and quality (Colla et al., 2015).

Humic and Fulvic Acids: Humic substances, particularly humic and fulvic acids, improve soil structure, increase microbial activity, and enhance nutrient availability. When applied to seeds, they stimulate root growth, leading to better nutrient absorption and crop vigor (Canellas et al., 2015).

Seaweed Extracts: Seaweed extracts, rich in plant hormones like cytokinins and auxins, have been widely used as biostimulants to improve growth, flowering, and fruit quality. They also enhance the plant's resistance to drought and salinity (Craigie, 2011).

Microbial Biostimulants (PGPRs and Mycorrhizal Fungi): Plant growth-promoting rhizobacteria (PGPRs) and mycorrhizal fungi are beneficial microbes that form symbiotic relationships with plants. They facilitate nutrient uptake, particularly phosphorus, and improve plant tolerance to biotic and abiotic stressors (Rouphael et al., 2015).

Mechanisms of Biostimulants in Enhancing Seed Yield and Quality

Enhancing Root Growth and Nutrient Uptake: Biostimulants improve root architecture, which increases root surface area and enhances the plant's ability to absorb water and nutrients. For example, humic acids improve root development by stimulating auxin-like activity, which supports the plant's growth and nutrient uptake capacity (Canellas et al., 2015).

Improving Photosynthesis and Biomass

Production: Biostimulants like protein hydrolysates and seaweed extracts boost chlorophyll synthesis and photosynthetic efficiency. Enhanced photosynthesis increases biomass production, which directly correlates with seed yield (Colla & Rouphael, 2020).

Stress Mitigation and Enhanced Plant Resilience: Biostimulants enhance the plant's resilience to stressors such as drought, salinity, and temperature fluctuations by inducing stress-response pathways and increasing antioxidant activity. For example, amino acids act as osmoprotectants and maintain cell integrity under water stress (Ertani et al., 2013).

Modulating Plant Hormone Levels: Many biostimulants, especially seaweed extracts, contain natural plant hormones that regulate growth processes, including cytokinins, auxins, and gibberellins. These hormones influence seed germination, flowering, and fruiting, which are essential for higher seed yields (Craigie, 2011).

Enhancing Nutrient Use Efficiency (NUE): Biostimulants improve plants' ability to utilize applied fertilizers more effectively. Studies have shown that protein hydrolysates increase nitrogen use efficiency, allowing crops to grow better with lower fertilizer inputs (Colla et al., 2015).

Effects of Biostimulants on Seed Yield

Improved Seed Germination and Emergence: Studies have shown that seed priming with biostimulants like humic acids and amino acids enhances germination rates and seedling emergence, leading to more uniform crop establishment. This early-stage benefit translates into stronger plants that produce higher yields (Canellas et al., 2015).

Enhanced Seed and Fruit Size: Biostimulants promote cell division and expansion, which can lead to larger seeds and fruits. For instance, seaweed extracts have been found to increase fruit size in tomato and other horticultural crops, resulting in higher market value and yield (Craigie, 2011).

Increased Crop Productivity in Stressful Environments: Biostimulants improve plant resilience to adverse conditions, which can prevent yield losses. For example, the application of amino acids has been shown to increase crop productivity under drought conditions by enhancing osmotic regulation and cellular stability (Ertani et al., 2013).

Effects of Biostimulants on Seed Quality

Enhanced Nutritional Quality: Biostimulants can improve the nutritional content of seeds, including protein and essential nutrient levels. For example, biostimulants rich in amino acids have been found to increase protein content in legume crops, enhancing their nutritional value (Calvo et al., 2014).

Improved Seed Storage and Viability: Biostimulants can enhance seed viability and shelf life by strengthening seedling vigor and protecting seeds from environmental stresses. This quality improvement is particularly valuable for seeds intended for storage and delayed planting (Rouphael & Colla, 2020).

Increased Content of Secondary Metabolites: Biostimulants can enhance the concentration of beneficial compounds like antioxidants, vitamins, and phenolics, which improve the nutritional and functional quality of produce. Seaweed extracts, for instance, have been shown to increase antioxidant levels in vegetables, contributing to their health benefits (Craigie, 2011).

Sustainable Benefits of Biostimulants

Reduced Need for Chemical Fertilizers and Pesticides: By enhancing nutrient uptake efficiency and improving resilience to pests and diseases, biostimulants help reduce reliance on chemical fertilizers and pesticides, supporting eco-friendly farming practices (Yakhin et al., 2017).

Contribution to Soil Health: Microbial biostimulants improve soil structure and fertility, fostering beneficial microbial communities that support sustainable nutrient cycling. These benefits are essential for long-term soil health and agricultural productivity (Rouphael et al., 2015).

Promotion of Climate-Resilient Agriculture: Biostimulants help plants adapt to climatic stresses, contributing to stable yields under variable environmental conditions. Their role in climate-resilient agriculture makes them a valuable tool for adapting to changing weather patterns (Calvo et al., 2014).

Challenges and Considerations in Biostimulant Application

Variability in Effectiveness: The efficacy of biostimulants can vary based on crop species, soil conditions, and application methods. Local field trials are often necessary to optimize biostimulant use for specific crops and environments.

Standardization and Quality Control: Biostimulant products often vary in composition and quality, impacting consistency in results. The lack of regulatory standards can make it challenging for farmers to select reliable products (Yakhin et al., 2017).

Cost and Accessibility for Smallholders: While biostimulants are cost-effective in the long term, initial costs can be a barrier for smallholder farmers. Strategies for making biostimulants more affordable and accessible will be critical for widespread adoption (Calvo et al., 2014).

Conclusion

Biostimulants offer an innovative and sustainable approach to enhancing seed yield and quality. By improving nutrient uptake, boosting plant resilience to stress, and reducing dependency on synthetic inputs, biostimulants contribute significantly to agricultural sustainability. Continued research on their mechanisms and field efficacy will support their integration into mainstream agricultural practices, providing a pathway to sustainable, high-quality food production.

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Digital Transformation in Agricultural Marketing: A New Era for Indian Farmers

Introduction

Agricultural marketing in India has traditionally been dependent on physical mandis (markets), middlemen and highly localized supply chains. This structure often resulted in inefficiencies, market information asymmetries and poor price realization for farmers. However, with the rapid penetration of the internet, smartphones and digital literacy, the agricultural sector has begun to embrace digital platforms as an innovative solution to bridge these longstanding gaps. Digital marketing in agriculture refers to the strategic application of digital tools such as e-commerce websites, mobile applications, cloud platforms, social media and SMS services to connect producers directly with buyers, input suppliers and service providers. These platforms enable data-driven decision-making, traceability, real-time price discovery and reduce the influence of intermediaries (Patil *et a*l., 2021).

Prominent platforms like e-NAM, ReMS, e-Choupal, Agmarknet and NCDFI eMarket exemplify this transformation. For instance, e-NAM, launched by the Government of India, has created a unified national digital market by integrating 1522 mandis across the country. Similarly, ITC's e-Choupal initiative uses internet kiosks to connect farmers with buyers, while Agmarknet delivers daily commodity prices via SMS and apps.

Key Digital Platforms and Initiatives

1. National Agriculture Market (e-NAM)

The e-NAM platform, an initiative of the Government of India, was launched on April 14, 2016. It is managed by the Small Farmers Agribusiness Consortium (SFAC) under the aegis of the Ministry of Agriculture and Farmers' Welfare. The platform aims to provide farmers with better marketing opportunities through a transparent online price discovery system and an online payment facility, thereby reducing the influence of middlemen. The e-NAM portal has been celebrating 8 successful years.

e-NAM has successfully integrated 1,522 mandis across 23 states and 4 Union Territories. It offers a pan-India electronic trading platform, ensuring fair price discovery and increased market access. The platform's features include an online trading and payment system, quality assaying and produce grading, information on prices and arrivals, and a nationwide license for traders.

A significant advancement is the "Platform of Platforms" (POP) under e-NAM, an advanced initiative launched by the Ministry of Agriculture & Farmers Welfare. The POP aims to integrate multiple service providers into the e-NAM ecosystem. It brings together various agri-tech platforms, service providers, logistics, fintech, and warehousing into a single digital interface to serve farmers, traders, and other stakeholders more holistically. Services integrated under POP include quality assaying (real-time lab reports), logistics (trucks, storage, cold chain), ePayments (NEFT, DBT, UPI), eLearning/advisory, FPO linkage, and financial services. The introduction of e-NAM 2.0 and logistics integration is expected to bridge gaps and enable meaningful pan-India trade, addressing fragmentation and supporting long-distance market linkages.

The impact of e-NAM has been notable. A study by Yadav (2018) found that the marketing efficiency of tomatoes under the post-unification of e-NAM was 2.11, which was higher than the pre-unification efficiency of 0.58. The study also showed improvements in the farmer's selling price and the price received by the farmer. A different study revealed that a majority of respondents (72.50%) perceived the transparency in weighment of e-NAM as "good," ranking it first among process-related effectiveness items.

2. Rashtriya e-Market Services (ReMS)

The ReMS scheme was launched in February 2014 by the Government of Karnataka in collaboration with NCDEX e-Markets Limited (NeML). The initiative aims to transform agricultural markets by promoting transparency, efficiency, and fair trade practices. It unifies 162 main and 354 sub-APMCs and covers a total of 92 commodities.

A study by Fathima (2019) in Karnataka showed that among 80 farmers, 45% utilized the ReMS infrastructure to a medium extent, and 26.25% showed high utilization. The study also highlighted challenges faced by farmers, such as lack of computer knowledge (92.50%), poor internet connectivity (75.00%), and delay in payment settlements (60.00%). Suggestions provided by farmers included the provision of computer education (100%), awareness programs about ReMS (95.00%), and simplification of the process (93.75%).

3. e-Choupal

ITC Limited launched the e-Choupal initiative in June 2000. It links rural farmers directly via the internet for the procurement of agricultural and aquaculture products like soybean, wheat, and coffee. There are 6,100 e-Choupals in operation in 35,000 villages across 10 states, covering 4 million farmers. ITC aims to expand e-Choupal 4.0 to 10 million farmers by leveraging technology and widening regional coverage. Each kiosk is managed by a Sanchalak, a trained local farmer, who serves around 600 farmers in a 5 km radius.

A study on e-Choupal usage in Uttar Pradesh found that major constraints perceived by farmers were a lack of awareness (Garrett's Mean Score of 52.98), difficulty in accessibility (44.73), and the information not being provided in the local language (24.88).

4. Agmarknet

The Agmarknet portal, launched in March 2000 by the Ministry of Agriculture, Government of India, provides easy access to commodity-wise and variety-wise daily prices and arrival information for more than 2,000 varieties and about 350 commodities. It has covered 3,918 markets across the country. The portal is accessible via web, mobile apps, and SMS, and provides analytical reports, including weekly and monthly trend analyses.

5. NCDFI eMarket

The NCDFI eMarket is the National Co-operative Dairy Federation of India's digital trading platform, launched on June 10, 2015. It is an internet-based electronic marketplace for dairy and allied commodities, aiming to improve price transparency, speed, and trade volume. The platform features forward and reverse auctions for products like dairy products, cattle feed, sugar, edible oils, and more. It also provides procurement solutions and e-auction services to the NCCF for trading pulses and other commodities under schemes like the Price Support Scheme (PSS) and Price Stabilization Fund (PSF). Operational modules include farmer registration, farmer procurement, inventory dispatch, and online farmer payments.

Mobile Applications for Agricultural Marketing

Mobile applications are playing an increasingly crucial role in agricultural marketing, providing farmers with real-time information and tools for decision-making.

- **Krishify Agriculture Kisan App:** Farmers can sell their produce, and trade cattle and fertilizers, with their GPS location displayed.
- **AgriCentral:** This application provides market prices for nearby markets as well as for all of India. Farmers can see market trends for their crops to decide when and where to sell their produce.
- **Uzhavan:** This app provides information about market prices in major markets of Tamil Nadu. A study found that farmers faced challenges with this app, such as a lack of training (92.22%), inadequate agricultural news (84.44%), and the app only functioning in online mode (71.11%).
- **IFFCO Kisan:** Farmers can get access to mandi prices, market status, and price trends, and both buyers and sellers can register their requirements.
- **iKhedut:** This app provides information on government schemes, subsidies, farm inputs, and market details in the Gujarati language.
- **Amul Farmers App:** This app is designed for dairy farmers supplying milk to Amul and provides information on milk slips, payment reports, and milk quality.

A study by Kumar (2023) in Haryana found that the most frequently used mobile application was Kisan Suvidha, with 85.3% of respondents using it frequently. Other apps like Crop Insurance and Pusa Krishi were also used frequently by 55% and 50% of the respondents, respectively.

Challenges and Constraints in Digital Adoption

Despite the significant prospects, the adoption of digital platforms in agricultural marketing faces several challenges. A study by Kumar et al. (2024) highlighted that farmers faced major constraints in accessing and benefiting from the e-NAM scheme. The most prominent challenges included limited participation of all traders in the scheme (96.00%), absence of awareness programs (93.00%), and incomplete information about e-marketing platforms (92.00%). Furthermore, issues such as failure of local traders and extension workers to communicate relevant information (90.00%) and low digital literacy among farmers (60.00%) significantly hindered adoption.

In a study on ReMS usage, farmers reported challenges such as lack of computer knowledge (92.50%), lack of understanding of the entire process (87.50%), and poor internet connectivity (75.00%). The need for timely market information and a proper help desk was also noted.

A study on e-Choupal found that constraints included lack of awareness (Garrett's Mean Score 52.98), inaccessibility (44.73), and power fluctuations (40.79).

Research by Nelson et al. (2025) on e-NAM in Himachal Pradesh found that the major obstacles were lack of awareness and technical illiteracy (Mean Score 11.86), no proper dissemination of information (10.56), and a complicated sales process (8.71).

Impact on Farmers and Market Efficiency

Digital platforms have a demonstrable positive impact on farmers. A study on cotton farmers in Hubballi, Karnataka, found that online farmers had a net return of ₹2,718.01 per bale, which was 56.59% higher than the ₹1,735.69 per bale for traditional farmers. The B:C ratio also improved for online farmers (1.48) compared to traditional farmers (1.30). The study also found that marketing costs for online farmers were 28% lower than for traditional farmers.

Furthermore, research indicates a positive and significant correlation between a farmer’s profile and their awareness of digital platforms. Education, annual income, training received, extension contact, innovativeness, mobile inclination, and decision-making ability were all found to be positively correlated with a farmer's perception of e-NAM and digital marketing applications. Age and credit acquisition had a negative and significant correlation, while farming experience, landholding, and social participation showed a non-significant relationship.

Conclusion and Future Thrust

Digital marketing is fundamentally transforming agricultural marketing in India by fostering transparency, reducing the role of middlemen, and improving price discovery through platforms like e-NAM, e-Choupal, and Agmarknet. Mobile applications are further empowering farmers with real-time updates and e-commerce functionalities, enabling them to make informed decisions.

However, to fully realize the potential of digital agriculture, a concerted effort is needed to overcome existing challenges. This includes implementing robust awareness programs, developing user-friendly interfaces, and providing inclusive digital training. Strengthening infrastructure to address connectivity gaps and offering strong policy support will be crucial to empowering farmers and integrating them effectively into modern agri-market systems. By focusing on these areas, India can ensure that the digital revolution in agriculture leads to greater prosperity and a more equitable market for all its farmers.

Future Thrust

- Expand regional coverage.
- Enhance digital literacy.
- Strengthen infrastructure.
- Promote platform interoperability.
- Focus on user-friendly design.
- Provide policy and institutional support.
- Encourage global market access.
- Leverage emerging technologies.

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CLIMATE CHANGE AND FORAGE FUTURES: CHALLENGES AND OPPORTUNITIES IN THE NORTH-WESTERN HIMALAYAS

Introduction

Climate change is reshaping global agriculture, with mountainous regions like the North-Western Himalayas being particularly vulnerable. In Jammu & Kashmir, forage availability is constrained due to limited cultivation during kharif and heavy dependence on subalpine and alpine pastures, which remain snow-covered for half the year. Grasses dominate these pastures, while legumes are scarce, resulting in low herbage yield and nutritive value, particularly at higher altitudes.

Rising global temperatures, shifting precipitation patterns, glacier retreat, and altered snowfall timing are already impacting water availability, pasture productivity, and forage quality across this ecologically sensitive region.

Climate Impacts on Forage Crops

Climate change is affecting both **quantity and quality** of forage crops:

- **Elevated CO_2** boosts growth in C3 plants (e.g., oats, alfalfa, cowpea) due to enhanced photosynthesis, often increasing yields by up to 30%. However, **C4 crops** (e.g., maize, sorghum) show modest responses.
- **Warming temperatures** accelerate crop development but may reduce yield due to shortened growth cycles or heat stress during critical stages like flowering.
- **Extreme weather events**—droughts, floods, and heatwaves—further reduce productivity, disrupt pollination, and affect plant survival.
- Glacier retreat and reduced snow have diminished stream flows, affecting summer irrigation and pasture regeneration.

Crop-Specific Climate Sensitivity

- **Sorghum**, drought-resistant and ideal for arid regions, performs well with supplemental irrigation but suffers under prolonged water stress.
- **Oats**, a major forage in Kashmir, are frost-tolerant but sensitive to heat stress during early growth and flowering.
- **Alfalfa**, a nitrogen-fixing legume, shows strong growth under elevated CO_2, but the benefit declines under drought and higher temperatures due to reduced photosynthesis and nitrogen fixation.

Forage Quality Under Changing Climate

The interaction between CO_2, temperature, and water availability influences forage quality:

- Elevated CO_2 often reduces **crude protein** and increases **carbon-to-nitrogen ratios**, leading to lower digestibility.
- **Warmer temperatures** raise lignin and fiber content, reducing palatability.
- Drought, paradoxically, may improve nutritional value in some grasses by delaying maturity and increasing protein content.
- Species mixtures may adapt over time; for instance, increased clover in grass-clover pastures may offset protein declines due to climate effects.

Mitigation and Adaptation Strategies

- **Soil Carbon Sequestration**: Promoting organic and conservation agriculture to enhance soil organic matter, mitigate CO_2, and boost resilience.
- **Natural Carbon Sinks**: Afforestation and protection of phytoplankton and forest systems to absorb atmospheric CO_2.
- **Climate-Resilient Varieties**: Breeding for high-temperature, drought-tolerant forage crops that respond to elevated CO_2.
- **Resource-Conserving Technologies**: Use of zero tillage and water-efficient systems to stabilize yield under climatic stress.
- **Diversified Farming**: Integrating horticulture and agroforestry with traditional forage systems to manage risks and improve farm income.
- **Policy Support**: Crop insurance, incentives for soil enrichment, and subsidies for climate-smart inputs.
- **Contingency Planning**: Adjusting sowing dates, crop choices, and water management strategies to minimize loss from erratic weather.

Conclusion

Forage production in the North-Western Himalayas is under mounting pressure due to climate change. While elevated CO_2 may benefit some crops, heat stress, erratic rainfall, and declining water resources are major threats. A multi-pronged approach—spanning agronomic innovation, ecological restoration, and supportive policies—is essential to secure fodder security and livestock productivity in the region.

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Traditional Method of Rice Bed Preparation in Telangana (Southern Plateau and Hills Region)

Abstract

This article describes the traditional method of rice bed preparation practiced in the Southern Plateau and Hills region of Telangana. The method, based on direct sowing during the monsoon, uses manual and animal-drawn implements, raised beds, and organic manure. It is a cost-effective approach that helps reduce waterlogging, control weeds, and maintain soil fertility, though it remains labour-intensive and dependent on timely rainfall.

Introduction

In Telangana's Southern Plateau and Hills agro-climatic zone, farmers have preserved age-old agricultural methods for rice cultivation. One of these is the traditional rice bed preparation using the direct sowing method during the monsoon season. This approach incorporates indigenous tools, animal labour, and organic manure, ensuring adaptation to local climate and soil conditions while sustaining crop productivity.

Step-by-Step Process of Rice Bed Preparation

1. Tillage Before Monsoon

Farmers till the field using a traditional country plough, ploughing in two perpendicular directions for thorough soil inversion. This is done before the onset of the monsoon to control weeds early and prepare the soil for sowing.

2. Sowing Day Preparation

On the day of sowing, a blade harrow is used to break down soil clods and produce a fine tilth. Weeds are removed manually to ensure an ideal seedbed.

3. Raised Bed Formation

Raised beds are made to prevent waterlogging during heavy rains. Adequate drainage between beds promotes root aeration and reduces disease risks.

4. Application of Organic Manure

Farmers broadcast goat or sheep manure evenly across the beds. This manure provides essential nutrients for germination and early seedling growth.

5. Sowing and Germination

Seeds are directly sown and lightly covered with soil for protection from birds and pests. Under good moisture conditions, seeds germinate within a few days, and by around 21 days seedlings are ready for transplanting.

Advantages

- Protection from Birds – Soil coverage shields seeds from bird damage.
- Avoids Waterlogging Damage – Raised beds protect against excess moisture.
- Better Weed Control – Pre-monsoon tillage reduces weed competition.
- Cost-Effectiveness – Use of traditional tools and organic manure lowers input costs.

Disadvantages

- Labour Intensive – Requires heavy manual work for ploughing, harrowing, and weeding.
- Dependence on Timely Rainfall – Success depends on rainfall shortly after sowing.
- Uneven Germination – Moisture variability can lead to patchy growth.
- Limited Mechanization – Incompatible with most modern farm machinery.
- Pest and Disease Exposure – Surface seeds can attract pests before germination.

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BENEATH THE BULBS: HOW SOIL PH AND ORGANIC MATTER STEER FUSARIUM BASAL ROT IN ONION

INTRODUCTION:

Onion (*Allium cepa* L.), a member of the family Amaryllidaceae (subfamily Allioideae), is one of the most widely cultivated and economically important spice crops worldwide. It is a low-altitude horticultural crop with a short growing season. Renowned for its distinctive flavour, aroma, and taste, as well as the therapeutic potential of its bioactive compounds, onion is popularly referred to as the "Queen of the Kitchen". In addition to its culinary significance, onion is valued for its nutraceutical properties, including cardiovascular, anti-cancer antidiabetic, and antibacterial properties. In 2021, the global onion cultivation area was estimated at 5,778,769 ha, with a production of 106.59 million tonnes (MT). India, China, Egypt, USA, and Turkey are the leading onion-producing countries.

The disease basal rot of onion is caused by the soil-borne fungal pathogen *Fusarium oxysporum* f. sp. *cepae*. The disease is characterized by yellowing of the leaves, which progressively dry, accompanied by root rot and eventual plant death. Soil pH and organic matter content are critical factors influencing the incidence of *Fusarium* basal rot. The pathogen thrives in slightly acidic soils. Raising soil pH toward neutrality can help suppress the disease by limiting the pathogen's access to micronutrients and promoting the activity of beneficial microorganisms. High soil organic matter enhances disease suppressiveness through increased microbial competition and antagonism by beneficial microbes such as *Pseudomonas* spp. and *Trichoderma* spp. Moreover, organic matter improves soil structure and nutrient availability, creating conditions less favorable for disease development. Therefore, soil management practices that optimize pH and enrich organic matter are crucial components of integrated strategies for controlling Fusarium basal rot in onion.

SYMPTOMS AND YIELD LOSS:

Fusarium basal rot (FBR) infecting onion and other Allium crops reduces the quantity of marketable bulbs and diminishes bulb size and quality. FBR incidence is strongly influenced by environmental conditions, particularly high soil moisture combined with elevated soil temperatures, with disease prevalence reported to range from 17% to 41% under such conditions. Infection can occur across a wide soil temperature range (15-32 °C), but disease development is most rapid at 28-32 °C.

Symptomatology

Initial symptoms appear as yellowing, curling, and dieback of leaves, starting from the tips and progressing downwards. Roots of infected plants become discoloured, turning dark brown to pink, and eventually rot. White fungal growth may be observed at the base of the bulb, and the basal plate that connects the roots to the stem often exhibits browning, dry rot, and cracking.

Economic Impact

FBR causes significant yield losses in both field and storage conditions. Yield losses can be substantial, with up to 45% loss in the field and 12-30% loss of bulbs during storage. In nurseries, losses may reach 70%, while in the field, the disease can destroy up to 50% of bulbs; during storage, losses of 30-40% are common. The severity of losses depends on the growth stage of infection and the environmental conditions of the region.

FACTORS INFLUENCING DISEASE SEVERITY:

Soil pH and organic matter (OM) are critical determinants of *Fusarium* basal rot (FBR) dynamics in onions.

Soil pH

F.o f. sp. *cepae* exhibits optimal infection at a pH of around 5.9, though growth may also peak between 6.5 and 7.0. *In vitro* tests indicate that mycelial growth reaches its peak at pH 6.5 (Yadav *et. al* 2014). Shifting soil pH toward neutral to slightly alkaline values (6.5–7.0) can reduce disease incidence by directly limiting pathogen activity, improving phosphorus availability, and decreasing aluminum toxicity to roots. The pathogen thrives in moderately acidic soils and warmer temperatures, conditions that favor both infection and disease progression. pH also influences soil microbial community structure.

Organic Matter (OM)

Organic matter exerts an equally significant influence. Soils with OM <1.0% are microbially poor, favoring *Fusarium* proliferation. Moderate OM (1.5-2.5%) supports balanced microbial activity, while 2.5-4.0% OM often creates suppressive conditions where antagonistic microbes outcompete *Fusarium*. However, excessive fresh OM (>5%) may transiently increase disease risk by providing substrates for both beneficial and pathogenic microbes. The suppressive potential of OM is contingent on type, decomposition stage, and integration with management strategies.

Optimal pH regulation combined with moderated OM inputs can synergistically reduce FBR pressure while promoting onion vigor and resilience.

CONTROL MEASURES:

Effective management of Fusarium basal rot (FBR) in onions requires an integrated strategy that simultaneously targets the pathogen at multiple stages of its life cycle and strengthens the plant–soil system. Crop rotation with non-host species such as cereals and legumes disrupts saprophytic survival of *F.o* f. sp. *cepae*, gradually lowering soil inoculum density over successive seasons. The use of resistant onion cultivars limits root penetration and vascular colonization, thereby reducing pathogen establishment.

Biological control agents (BCAs) such as *Trichoderma* spp. (*T. viride*, *T. harzianum*), arbuscular mycorrhizal fungi, *Bacillus subtilis*, and *B. amyloliquefaciens* suppress *Fusarium* through niche competition, mycoparasitism, and antibiosis. The combined application of fluorescent *Pseudomonas*, *T. harzianum*, and AMF significantly outperformed the uninoculated treatment, lowering disease incidence and severity by 74% in pots and 67%

in the field (R. Srivastava *et. al* 2010). Applications of *Bacillus* and *Trichoderma* reduced wilt incidence by 26.8% and 37.5%, respectively (Ali *et. al* 2023). These organisms produce cell wall-degrading enzymes (e.g., chitinases, glucanases) and antifungal metabolites that inhibit hyphal growth. Soil solarization, achieved by covering moist soil with clear polyethylene sheets to raise topsoil temperatures above 45 °C, denatures fungal proteins, disrupts cell membranes, and significantly reduces viable propagules. Sanitation practices such as removing and destroying infected plant debris, disinfecting tools, and avoiding irrigation water contamination further limit pathogen spread.

Organic amendments provide both direct and indirect suppression of *Fusarium*. Well-decomposed farmyard manure and compost enhance soil microbial diversity, fostering antagonistic microbes that compete for infection sites and nutrients. Vermicompost enriches the soil with beneficial fungi and bacteria. Green manure crops like sun hemp, cowpea, and dhaincha release phenolic compounds that stimulate disease-suppressive microflora. Green manure amendments with rapeseed and Ethiopian mustard lowered disease incidence by 21% and 30% and reduced disease severity by 23% and 29%, respectively (Sintayehu *et. al* 2014). Neem cake contributes azadirachtin, which disrupts fungal growth and reproduction, while mustard cake releases isothiocyanates natural biofumigants that inhibit spore germination.

Biochar, particularly when applied with compost, offers a porous habitat for beneficial microbes, improves nutrient retention, and sustains microbial activity. This reduced wilt incidence by 2.5% (Ali *et. al* 2023).Other amendments, including composted poultry manure, sugarcane filter press mud, and cocopeat compost, enhance soil aeration, organic carbon levels, and water-holding capacity, strengthening root health and resilience.

Combining solarization with organic amendments or biological control agents often enhances its effectiveness and can improve onion yield. Significant yield increases were observed in plots treated with solarization alone, metham sodium, and compost applied after solarization (Carrieri *et. al* 20013).

When these cultural, biological, and organic measures are applied in synergy, they transform the soil from a conducive to a suppressive environment, reducing Fusarium activity while promoting a robust, disease-resilient onion production system.

IMPORTANT CONSIDERATIONS AND LIMITS:

This information is crucial for implementing Integrated Nutrient Management (INM) , a balanced strategy that blends organic, inorganic, and biological nutrient sources to provide a steady nutrient supply while maintaining long-term soil health. Equally important is the timing of organic matter application. Incorporating organic materials during land preparation or before transplanting ensures sufficient decomposition and nutrient release, while preventing the negative impacts of excessive application at later growth stages, such as reduced bulb quality and compromised storage life. Excessive nutrient inputs can lead to imbalances that negatively affect onion yield and quality, increase the incidence of culls, bulb rot, and thick neck formation, and pose environmental risks such as nutrient leaching and soil degradation.

Table 1 List of organic amendments and their recommended rate		
Organic Amendment	**Recommended Rate (per hectare unless specified)**	**Notes**
Farmyard Manure (FYM)	25 tonnes/ha	Incorporate well-decomposed FYM during land preparation. Some sources suggest rates of 15-20 t/ha.
Compost	2-3 tonnes/acre (4.9-7.4 t/ha) during land preparation	Enhances soil organic matter and improves storage quality.
Vermicompost	4 tonnes/acre (9.9 t/ha) before transplanting	Can be incorporated one week before transplanting.
Green Manure	Incorporate before planting (e.g., sunhemp)	Improves soil properties and adds up to 10 tonnes of organic content per acre (24.7 t/ha).
Cow Dung	10-15 tonnes/ha when combined with inorganic fertilizers	Combined application with mineral fertilizer has been shown to improve onion yields.
Poultry Manure	Organic manures equivalent to 75 kg N (~7.5 t/ha) as a basal dose for various onion types	Recommended alongside other organic and inorganic fertilizers as part of an integrated nutrient management strategy. Combining with inorganic fertilizers like RDF (Recommended Dose of Fertilizer) can enhance yield and quality.

CONCLUSION:

Fusarium basal rot poses a significant threat to onion production, requiring a comprehensive and integrated management approach. Optimizing soil health through the judicious use of organic matter while simultaneously considering its potential limitations forms a crucial foundation. Organic amendments improve soil structure, enhance microbial activity, and stimulate antagonistic microbes that suppress *Fusarium* pathogens. However, excessive application can alter nutrient balance, favour disease development, and compromise bulb quality.

An effective FBR management program integrates multiple strategies, including **Resistant cultivars** to reduce disease incidence and severity. **Crop rotation** with non-host crops for at least 3-4 years to break the disease cycle. **Biological control agents** such as *Trichoderma spp.*, *Bacillus subtilis*, and mycorrhizal fungi to suppress *Fusarium* populations and enhance plant defence. **Soil pH management**, as slightly acidic to neutral conditions are less conducive to pathogen proliferation. **Sanitation and hygiene** measures, including removal of infected plant debris, sterilization of tools, and use of disease-free planting material. **Drainage management** to avoid prolonged soil moisture, which favours pathogen activity. **Balanced nutrient management**, ensuring adequate potassium and micronutrients to strengthen plant tissues and disease resistance.

Adopting **Integrated Nutrient Management (INM)** combining organic, inorganic, and biological nutrient sources—further promotes soil resilience and sustained crop productivity. Continued **research, on-farm trials, and adaptive management** will be vital to refine these approaches and develop region-specific, practical, and cost-effective solutions. Such integrated measures not only protect onions from Fusarium basal rot but also contribute to long-term soil health, productivity, and profitability.

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Future Harvest: An Artificial Intelligence for Horticulture

Abstract

Artificial intelligence (AI) refers to the creation of intelligent machines capable of performing tasks that typically require human intelligence. It is a branch of computer science focused on developing both physical and virtual systems that can think, learn and act like humans, achieving comparable performance in cognitive tasks through logical reasoning. In horticulture, AI has a wide range of applications. It can detect plant diseases, improve crop yields, manage weeds, identify nutrient deficiencies and optimize fertilizer use. By learning from past data, AI enables fast and accurate decision-making. Machine learning, a subset of AI, develops tools and algorithms to solve such problems. For example, AI-based automated systems using computer vision and machine learning incorporating like features can identify the ripest fruits and vegetables for harvest. AI technology not only diagnoses issues quickly but also recommends precise corrective actions. It excels in monitoring data, finding solutions promptly and supporting precision agriculture. The ongoing digital transformation of agriculture and horticulture driven by industrialization, mechanization, networking and data management promises significant benefits for both producers and consumers. With the rise of digital agriculture, the next major revolution in farming is already underway.

Keywords: Horticulture, Artificial Intelligence (AI), Machine Learning Computer Vision, Precision Agriculture and Digital Transformation

Introduction

India has diverse soils, climates and agro-ecological zones support a wide variety of horticultural crops, including fruits, vegetables, medicinal, aromatic, and ornamental plants. These crops are vital for nutrition, medicine, aesthetics, and rural livelihoods, with fruits and vegetables making up 90% of production. India ranks second globally in fruit and vegetable output after China. Despite its economic importance, horticulture remains less digitalized and vulnerable to biotic and abiotic stresses. Modern technologies, especially artificial intelligence (AI), can enhance productivity by optimizing planting, irrigation, harvesting, and monitoring. AI offers real-time insights on weather, soil, pests, and crop conditions, improving efficiency, reducing labor needs, and strengthening the food supply chain (Manaware, 2020).

Advantages of AI in the Horticultural Sector

AI offers several key benefits for horticulture:

- Enables more efficient production, harvesting and marketing of essential crops.
- Detects defective produce early, thereby enhancing the chances of healthy crop yields.
- Strengthens agro-based businesses by improving operational efficiency.
- Supports applications such as automated machinery adjustments, weather forecasting and rapid identification of diseases or pests.
- Enhances crop management practices and provides solutions to challenges like climate variability, pest infestations and weed control factors that often reduce yields.
- Complements rather than replaces human labor, helping farmers improve processes instead of eliminating jobs.

Applications

Produce Maturity Identification

Determining fruit ripeness involves capturing images of crops under white or UV-A light. This is particularly valuable for highly perishable horticultural products, where farmers can classify produce into different maturity grades based on the crop or fruit type and sort them accordingly before sending them to market. Harvesting at the optimal maturity stage not only improves quality but also extends post-harvest shelf life.

Fig: Produce Maturity Identification

Automation in Irrigation

The integration of the Internet of Things (IoT) with artificial intelligence (AI) has transformed irrigation into a highly efficient and automated process. IoT-based smart irrigation systems use a network of soil moisture sensors, weather stations, and data analytics platforms to monitor soil water content, temperature, humidity, and other meteorological factors in real time. These systems can determine exactly when and how much water a crop needs, preventing both under- and over-irrigation. Irrigation is traditionally one of the most labor-intensive tasks in farming, requiring manual monitoring of field conditions and extensive physical effort. However, with AI, the process becomes far more streamlined. AI algorithms process historical weather patterns, soil quality data, and crop-specific water requirements to make predictive decisions. For example, if the system detects low soil moisture and forecasts no rainfall in the coming days, it can automatically trigger irrigation with the optimal amount of water needed. This level of automation not only conserves water resources but also reduces labor costs and ensures that crops receive consistent care, ultimately leading to higher yields and improved quality.

AI in Shaping the Future of Farms

1. Drones in Agriculture

Drones, or unmanned aerial vehicles (UAVs), have become indispensable tools in modern precision farming. Equipped with high-resolution cameras, multispectral sensors, and AI-powered analytical software, drones can conduct in-depth field analysis, perform long-range crop spraying, and provide high-efficiency crop monitoring. Using drone technology, farmers can:

- Assess soil conditions to determine if an area is suitable for planting or requires watering.
- Monitor crops for signs of stress such as dehydration, nutrient deficiencies, or pest infestations.

- Identify problem areas early, allowing for targeted interventions that save time and resources.

Fig: Fruit Harvesting Robots

Cameras on drones are often trained with AI models to recognize visual anomalies, such as yellowing leaves (nutrient deficiency) or irregular patches (pest damage). All collected data is processed to predict the optimal harvest period, helping to avoid premature or delayed harvesting. Drones also excel at crop spraying—covering large areas quickly, evenly, and with minimal waste. Compared to conventional spraying equipment, aerial spraying with drones is up to five times faster, making them a cost-effective and time-saving solution. The ability to perform real-time scanning and adjust spraying patterns on the fly ensures that every plant receives the necessary treatment without excessive chemical use (Kumar *et al.*, 2023).

2. Robotics in Greenhouses

Greenhouses have also embraced automation through robotic arms and AI-driven systems. These robotic arms are capable of performing complex 3D movements with high precision, such as:

- Lifting potted plants from carriers.
- Placing them onto tables or trays in exact positions.
- Rearranging plants for optimal spacing and growth conditions.

Even when plants are misaligned, AI-guided robotic systems can adjust their grip and movement to handle them safely. This automation reduces the manual labor required for repetitive greenhouse tasks, increases operational efficiency, and ensures that plants are handled consistently and gently, reducing damage. Additionally, such systems can be integrated with environmental sensors to automatically adjust lighting, temperature, and humidity for optimal plant health.

3. Fruit Harvesting Robots

Fruit-picking robots represent one of the most advanced applications of AI and automation in horticulture. These robots must delicately remove fruit without damaging branches, leaves, or the produce itself. They achieve this through a combination of computer vision and mechanical precision:

- **Detection**: Cameras mounted on the robot's arm capture images of the tree canopy. The AI system processes these images to differentiate between fruit and foliage based on color, shape, and size.

Fig: Fruit Harvesting Robots

- **Verification**: The detected color is compared to reference data stored in memory. If a match is confirmed, the robot moves to harvest the fruit.
- **Obstruction Management**: If leaves block the view of the fruit, an air jet gently moves

the foliage aside to allow for accurate identification.

- **Harvesting**: The robotic gripper applies just enough pressure to detach the fruit without bruising it. The design of the gripper varies according to the type of fruit or vegetable being harvested.

AI-Powered Robotics and Systems in Horticulture

1. Lettuce Weeding and Thinning Robots

Specialized robots for lettuce weeding and thinning are being used to significantly enhance lettuce productivity. Equipped with high-resolution vision systems and advanced artificial intelligence algorithms, these robots inspect each individual plant with precision. The AI system then decides which plants should be retained for optimal growth and which should be removed to reduce overcrowding. By making these selective decisions in real time, the robot ensures that each plant receives adequate sunlight, nutrients, and space, thereby improving both yield and quality. Such automation also reduces the need for manual labor in repetitive, time-consuming tasks, allowing farmers to focus on higher-level management operations.

2. Automated Tractors

The agricultural tractor, a cornerstone of modern farming for over a century, is now undergoing a transformation into a fully autonomous machine. By integrating sensors, radar systems, GPS navigation, and sophisticated AI software, automated tractors can perform plowing, planting, and other field operations with minimal human intervention. These self-driving machines are capable of working long hours without fatigue, maintaining consistent accuracy, and reducing human error. Farmers will soon be able to delegate entire field preparation tasks to robotic tractors, improving efficiency and lowering operational costs.

AI in Horticulture: Current Approaches and Achievements

A. Blue River Technology – Precision Weed Control

Weed management is a critical challenge for farmers, especially as more than 250 species of weeds have developed resistance to common herbicides. To address this, California-based startup Blue River Technology has developed the "See & Spray" robot, which uses computer vision and AI algorithms to identify weeds in real time and apply herbicides only where needed. This precision spraying approach can reduce herbicide use by up to 90%, minimizing environmental impact while cutting costs. In addition to weed control, the system can also target and apply fertilizers directly to individual plants, ensuring efficient nutrient management.

B. Crop Harvesting Solutions

Labour shortages in agriculture have caused substantial economic losses, particularly in labor-intensive crops such as strawberries. In response, Harvest CROO Robotics, in collaboration with Florida-based Wish Farms, developed an autonomous strawberry harvester capable of picking and packing strawberries directly in the field. First introduced in 2017, this machine uses AI to identify ripe strawberries, gently harvest them, and place them into containers, significantly reducing reliance on manual labor while ensuring timely harvesting to maintain fruit quality.

C. AI for Monitoring Crop and Soil Health – PEAT's Plantix

Berlin-based agricultural technology startup PEAT has created Plantix, a deep learning-based mobile application designed for diagnosing plant pests, diseases, and soil nutrient deficiencies. Using machine vision, farmers can simply take photographs of affected plants or soil samples, and the AI-powered system will analyze the images to detect possible problems. Plantix can identify nutrient deficiencies, pest infestations, fungal infections, and other crop health issues, providing farmers with recommendations for corrective measures. This enables faster decision-making, reduces crop losses, and supports sustainable farming practices by ensuring timely and targeted interventions.

D. Trace Genomics – Machine Learning for Soil Diagnostics

Trace Genomics, a California-based company, provides cutting-edge soil analysis services for farmers, using machine learning to diagnose soil defects. Similar in concept to the Plantix app, this system goes a step further by offering a comprehensive breakdown of a soil's health profile. The company, supported by Illumina as a lead investor, has developed a platform that analyzes soil samples sent by farmers. Once processed, users receive a detailed report outlining the soil's strengths, weaknesses, and overall fertility status. This empowers farmers to make informed decisions about crop selection, nutrient management, and soil amendment practices.

E. Farm Shots – Satellite and Drone-Based Crop Monitoring

Based in Raleigh, North Carolina, Farm Shots specializes in analyzing agricultural data collected through satellite imaging and drone surveys. The company's primary goal is to detect plant diseases, pest infestations, and nutrient deficiencies before they cause significant yield losses. One of its major contributions is optimizing fertilizer usage—its software can pinpoint exactly where fertilizer is needed, potentially reducing fertilizer application by up to 40%. Farm Shots leverages hyperspectral imaging and 3D laser scanning to capture high-resolution data capable of distinguishing individual fields, plots, and even single plants. This high spatial resolution, combined with the temporal advantage of tracking changes throughout the growing season, provides farmers with unparalleled insights into crop health. These technologies are scalable, making it possible to monitor plant health across thousands of acres efficiently

F. aWhere – Satellite-Based Agronomic Intelligence

aWhere, headquartered in Colorado, uses a combination of satellite imagery and machine learning algorithms to deliver actionable insights to farmers. Their system monitors agricultural land to detect diseases, identify pests, forecast weather conditions, and evaluate the sustainability of crop production. The platform processes more than one billion points of agronomic data each day, covering variables such as temperature, rainfall, wind speed, and solar radiation. These measurements are compared with historical climate data from anywhere in the world, enabling highly localized and accurate decision-making.

Expert Systems in Agriculture

Agriculture today is a sophisticated and data-intensive industry that requires integrating knowledge from multiple disciplines. Farmers often rely on agricultural experts for guidance in crop management, pest control, soil health, and weather forecasting. However, in many cases, expert advice is not readily available when needed. To address this challenge, expert systems—also known as knowledge-based systems (KBS)—have been developed. An expert system is a specialized computer program designed to replicate the decision-making processes of a human expert. In agriculture, these systems integrate expertise from fields such as plant pathology, entomology, horticulture, agronomy, and agricultural meteorology into a unified decision-support platform. They can provide farmers with customized, situation-specific advice, even in the absence of direct expert consultation. Some notable expert systems developed for horticultural crops include:

- **Cuptex** – An expert system for cucumber crop production.
- **Citex** – Designed for the cultivation and management of orange orchards.
- **Tomatex** – Tailored for tomato production.
- **Limex** – A multimedia expert system for lime production.

These tools combine scientific knowledge, real-time field data, and AI-driven analytics to provide timely recommendations, thereby improving crop quality, optimizing resource use, and increasing farm profitability.

Artificial Intelligence in Protected Cultivation

AI in Greenhouse Cultivation

Greenhouse farming is already automated, but AI takes it to new levels of precision by processing real-time crop and environmental data to adjust lighting, irrigation, temperature, nutrients, and ventilation. It predicts yields, improves quality, optimizes resources, and supports sustainabilityespecially important for large greenhouse networks facing labor shortages and rising demand. AI can also link growing conditions with post-harvest quality by adjusting parameters based on consumer feedback to extend shelf life.

Plant Phenotyping & Crop Sensors

Plant phenotyping measures traits like growth rate, architecture, and composition, now used in production to maintain crop health. Digital systems use cameras, depth sensors (e.g., Intel RealSense), and LiDAR to gather 3D plant data. To overcome dense crop occlusion, mobile platforms such as trolleys, drones, and robotic arms capture plants from multiple angles. AI then processes these images into accurate 3D models for analysis.

Digitalisation and AI for Crop Physiology Monitoring

Physiological performance, especially photosynthesis, is key to crop monitoring. Non-destructive tools like chlorophyll fluorescence imaging and thermal imaging can assess photosynthetic efficiency and detect stress early. Imaging spectroscopy further enables real-time, in-field chemical analysis of pigments, sugars, proteins, and water, replacing slow, destructive lab methods. AI-powered image segmentation enhances precision by automatically identifying and analyzing plant parts.

The Role of AI in Data Integration and Decision-Making

Spectral cameras and other high-resolution sensors generate enormous volumes of data, which can be difficult for human operators to process. AI techniques are therefore essential for extracting meaningful information from these datasets (Mishra *et al.*, 2020). AI algorithms can:

- Filter noise from raw data.
- Identify patterns and correlations between environmental conditions and crop traits.
- Combine outputs from multiple sensors into a unified decision-making model for growers.

Limitations of Artificial Intelligence in Horticulture

Despite its potential, the adoption of Artificial Intelligence (AI) in horticulture faces several challenges. In many parts of the world, farmers have limited exposure to advanced machine learning and AI-based solutions, making their acceptance and effective utilization difficult. The high initial cost of AI technologies is another significant barrier, especially for small and medium-scale farmers who may not have access to sufficient financial resources. Furthermore, AI systems require large volumes of high-quality data for training algorithms and ensuring accurate predictions. Collecting, storing, and processing this data can be technically demanding and expensive.

Challenges and Future Scope

The horticulture sector continues to face pressing issues such as inadequate irrigation infrastructure, unpredictable temperature fluctuations, declining groundwater reserves, food shortages and post-harvest wastage. The future of sustainable horticulture depends heavily on adopting cognitive and digital solutions that can address these concerns effectively. However, the application of autonomous decision-making systems and predictive analytics in farming is still at a relatively early stage. AI can be used to forecast weather patterns, assess land quality, monitor groundwater levels, predict pest or disease outbreaks, and determine optimal crop cycles. AI-enabled sensors, when integrated into robotic harvesting equipment, can collect real-time data for better operational decisions. It is estimated that AI-powered advisory systems could potentially increase horticultural productivity by up to 30%. Nevertheless, farmers must adapt to the digital transformation trend, embracing AI to enhance efficiency and resilience in their practices. This transition marks the beginning of a new agricultural revolution—one that demands innovative, resource-efficient strategies to meet the needs of a growing global population (Dhakad et al., 2024).

Conclusion

Artificial Intelligence in agriculture and horticulture not only automates routine tasks but also facilitates precision farming, leading to higher yields, improved crop quality, and reduced resource consumption. Labour constitutes one of the largest expenses in horticulture—often exceeding 50% of total production costs due to the intensive care and skill required for high-value crops.

AI technologies can optimize labour usage, ensure the efficient application of herbicides and fertilizers, and minimize crop losses by enabling timely harvesting. By integrating AI across various horticultural applications, farmers can boost productivity while reducing production costs. The use of AI will transform research and development in horticulture, promoting innovation in areas such as drone-based imaging, automated processing, and intelligent greenhouse systems. As AI-based solutions advance, they will bring more efficient, sustainable, and scalable approaches to crop production. Ultimately, AI represents a technological revolution in horticulture—a powerful tool to meet the food demands of the world's growing population. It will empower farmers with data-driven insights, challenge them to make better decisions, and contribute to a more sustainable agricultural future.

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Alternative Animal Feed: The Potential of Silkworms

Abstract

Silkworm pupae are beneficial insects for human health due to their high nutritional value and more importantly, the variety of pharmacological effects they can produce when consumed. Currently, there is a lot of interest in the medicinal applications of silkworm pupae. In recent years, the biological roles of domestic silkworm pupae have been gradually identified and confirmed, especially their beneficial effects on human health. Research indicates that silkworm pupae have positive effects on lowering blood pressure, controlling blood sugar and fat, protecting the liver, enhancing the immune system and having antibacterial, anticancer and antiapoptotic qualities. However, nothing is known about the pharmacological mechanisms and systemic safety of silkworm pupae. Spent silkworm pupae are a waste product that is commonly disposed of outside or turned into fertilizer. Valuable oil that is used in industrial products like paints, varnishes, soaps, candles, polymers, medications and biofuels can be derived from it. Sometimes the removed meal is used to make chitin, the main component of the exoskeleton and a long-chain polymer of N-acetylglucosamine. Silkworm pupae are considered a delicacy in portions of China, Japan, Thailand, and other Asian countries that make silk, and people have long eaten them. Because of its high protein content, silkworm pupae meal can be used as animal feed, especially for ruminants and monogastric animals like fish, pigs, and poultry.

Introduction

India, the world's second-largest producer, produces about 18,500 metric tons of raw silk annually. Approximately 90% of the world's silk is produced by the cultivated mulberry silkworm, *Bombyx mori*, which is the main source of silk. To make silk, cocoons are collected when they are in pupal stage. To obtain a continuous and long silk strands, the pupa must be destroyed before it produces enzymes that dissolve the cocoon. The cocoon is treated with alkaline solutions, like sodium hydroxide, or boiled and dried (Cho, 2010). More than five thousand silkworms are needed to produce one kilogram of silk. As many as 2,000 cocoons are required for a silk garment. Silk is made from spun and woven cocoon threads, which are long strands that make up the inner structure formed by larvae to protect themselves during the pupal stage. Every kilogram of raw silk produced is discarded along with about 8 kg of wet pupae or 2 kg of dry pupa.

If fresh pupae are not used effectively, 60–70% of the 1.2–1.5 lakh metric tons of pupae generated in India each year are considered waste. There are serious disposal and environmental concerns because over 65% of fresh pupae in areas where silk is produced wind up as trash. Spent pupae are not only waste but also a possible resource due to their high biodegradability and nutrient content. Excellent oils that are high in unsaturated fatty acids, bioactive compounds like chitin and α-linolenic acid and about 55–60% protein (on a dry weight basis) make up their composition. If this massive volume is not managed or recycled, it may pose health hazards and cause environmental damage in rural sericulture zones. One of the most promising thing is to convert discarded pupae into animal feed. Due to their high protein and fat content, dried silkworm pupae make excellent feed elements for pigs, fish and poultry. This could reduce reliance on costly protein sources such as fishmeal and soybean meal (Rodríguez-Ortiz *et al.*, 2024). Additionally, silkworm pupae oil, which is rich in omega-3 fatty acids, can be extracted and used in food supplements, cosmetics, and medications.

Additionally, pupal shells can be utilized to produce chitin and its derivative chitosan, which are employed in biodegradable packaging, medicine, agriculture and water purification. Due to its great nutritional value, silkworm pupae are even consumed by humans in several regions of Asia. Using leftover silkworm pupae not only promotes sustainability but also creates new sources of income in silk-producing regions (Cho, 2010). By encouraging the construction of small-scale pupae processing facilities and raising public awareness of their potential use, this valuable by-product can be transformed into a sizable financial asset. Utilizing the 60–70% waste generated by fresh pupae effectively can enhance the concepts of the circular economy, encourage sustainable rural development in India (Chandrasekharaiah *et al.*, 2004) and reduce the environmental impact of the silk industry. A significant by-product of the silk reeling business, silkworm pupae (SWP) have great nutritional and medicinal value and can be utilized as an alternative dietary supplement (De Foliart, 2006). About 8.014 kg of wet and 2 kg of dry SWP are produced as waste byproducts for every kilogram of raw silk. SWP is made up of 18 amino acids, including all of the necessary ones, proteins (about 62%), fatty acids (about 30%), vitamins, and minerals. Due to its high nutritional content, it can be used as a meal supplement for the rearing animals (Fish, livestock, poultry, piggery etc). SWP has long been consumed in some Asian nations, such as the Northeastern Indian provinces. The future applications of SWP in pharmaceuticals, healthcare items and nutritional supplements has been critically discussed.

Silkworm pupae meal

The remarkable nutritional value of silkworm pupae meal is well-known, particularly when it is given to feed as a high-protein supplement (Sadat *et al*., 2018). On a dry matter (DM) basis, the crude protein content frequently ranges from 50% to over 80%, especially after the meal has been defatted. Significant levels of essential amino acids, such as methionine and lysine which account for around 2-3% and 6-7% of the total protein composition respectively, are present (Sadat *et al*., 2018). However, about 73% of the crude protein is really protein based on amino acid analysis (Sheikh *et al*., 2018). The primary reason for this disparity is the nitrogen in chitin, a substance found in silkworms that raises crude protein levels.

The chitin content of pupae meal is rather modest, ranging from 3 to 4% of the DM. When combined with insoluble proteins, acid detergent fibre (ADF) levels, which have been demonstrated to range from 6% to 12% DM, may further increase the fibre content. When the meal is not defatted, a significant quantity of fat-typically 20% to 40% DM-is kept in it. On the other hand, defatted types often contain less than 10% oil (Sangha *et al*., 2024). The mineral content of silkworm pupae meal is generally between 3% and 10% DM, which is lower than that of other feed ingredients derived from animals. Polyunsaturated fatty acids, particularly linolenic acid (18:3) are abundant in the oil extracted from silkworm pupae and can make up anywhere between 11% and 45% of the total fatty acid profile (Sadat *et al*., 2018).

1. Silkworm pupa meal for Ruminants

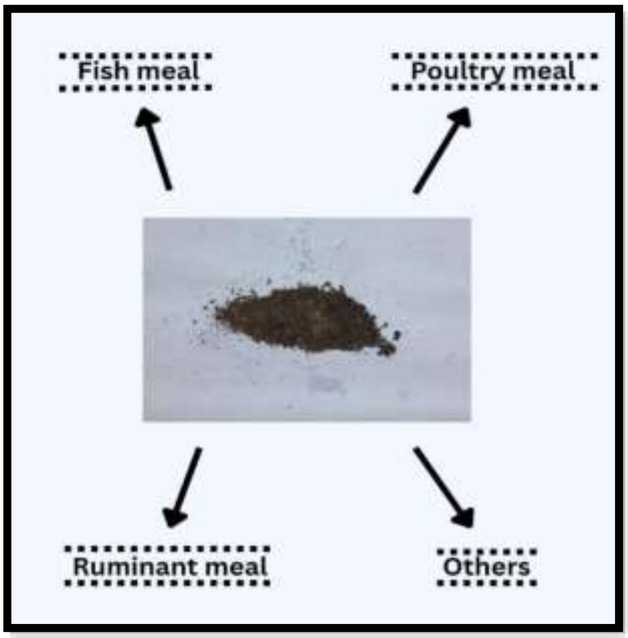
Silkworm meal is a highly nutritious protein supplement for ruminants, valued for its high levels of rumen undegradable protein (RUP) and well-balanced amino acid profile. However, its high fat content limits its direct use in large quantities, making fat extraction an important processing step when incorporating silkworm meal into ruminant diets.

Table.1 Silkworm pupa meal

Parameter	Unit	Avg	SD	Min	Max	Nb
Ash	% DM	5.4	2.4	3.3	10.6	11
Crude fibre	% DM	3.7	1.1	2.5	5.8	6
Ether extraction	% DM	25.3	9.0	6.2	37.1	10
Dry matter	% as fed	90.5	4.4	81.1	97.5	9
Crude protein	% DM	61.0	7.0	51.6	70.0	10

The In-situ nitrogen degradability of silkworm meal is relatively low, particularly at a rumen outflow rate of 5% per hour. Reported effective degradability values are around 29% and 25% for undefatted silkworm pupae and even lower-approximately 20% for defatted meal. This indicates a substantial amount of bypass protein, especially in the defatted form, which also contains a higher concentration of crude protein. Notably, lysine and methionine two essential amino acids often limiting in dairy production, exhibit low ruminal disappearance rates of 26% after 24 hours, further emphasizing the potential of silkworm meal as a valuable source of RUP containing these critical amino acids (Chandrasekharaiah *et al.*, 2004). However, the digestibility of this bypass protein in the intestines is relatively moderate, with an estimated digestibility of 53% based on in vitro pepsin-pancreatin solubility tests.

Fig. 1 Different types of silkworm pupa meal



2. Silkworm pupa meal for Pigs

Silkworm pupae meal shown to be a suitable substitute for conventional protein sources in two studies. In Brazil, pigs' growth and finishing diets could contain up to 100% undefatted silkworm meal in place of soybean meal, with no discernible impact on carcass attributes or growth performance. When the substitution rate exceeded 50%, intake was negatively impacted, which was explained by either a reduced palatability or a higher calorie density of the meal. Nonetheless, a higher feed conversion rate offset the lower consumption, which might have been brought on by the silkworm-based diet's increased lysine content. Pigs raised in India could be fed silkworm meal in place of fish meal without any changes.

3. Silkworm pupa meal for Poultry

Silkworm pupae meal is a high-protein substitute for chicken feed. Lysine and methionine digest at roughly 94% and 95% respectively, indicating that it has adequate amino acid availability (Dafur, 2007). Unless otherwise indicated, the silkworm pupae meal used in most of the cited investigates was not removed; however, the literature usually fails to make this clear (De Foliart, 2006).

4. Utilization in Broiler Nutrition

Research on broilers has shown that using silkworm pupae meal to replace up to 50% of the principal protein source-usually fish meal-is often both safe and effective (De Foliart, 2006). However, mineral supplements may be required. Despite efforts at complete replacement, growth performance is frequently adversely affected. The inclusion percentage of broiler feed is normally between 5 and 6% (Rodríguez-Ortiz *et al.*, 2024).

Table.2 SWP Containing Minerals

Mineral	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	4.0	3.0	0.7	8.4	6
Zinc	mg/kg DM	244	126	79	310	3
Magnesium	g/kg DM	3.9	2.5	1.9	6.5	3
Iron	mg/kg DM	320	67	262	395	3
Manganese	mg/kg DM	20	9	9	28	2
Magnesium	g/kg DM	3.9	2.5	1.9	6.5	3

5. Fish

A significant source of protein for many fish species, especially cyprinids, is silkworm pupae (Borthakur *et al.*, 1998). Using up to 50% non-defatted silkworm pupae meal in place of fish meal improved feed efficiency and nutrient retention in common carp (*Cyprinus carpio*). As a result, meat quality and growth were sustained. Feeding silver barb fingerlings (*Barbonymus gonionotus*) silkworm food (Cho, 2010) which made up over 38% of their protein, was the most effective way to promote their development. To increase development and survival, 50% defatted silkworm pupae were fed Mahseer (*Tor khudree*) meals at 5% of body weight. Furthermore, in cultivation systems containing Indian main carps (Catla, Rohu, and Silvercarp), fresh or fermented silkworm pupae were successfully substituted for fish feed without adversely affecting performance (Cho, 2010).

Conclusion

The silkworm pupae (SWP), a major by-product of the silk industry, are a resource that is neglected but extremely important. With India producing more than 1.2 to 1.5 lakh metric tons of SWP a year, 60 to 70 percent of which is wasted, efficient use has significant positive effects on the environment and the economy. Rich in vital amino acids, unsaturated fats, vitamins, minerals and protein (up to 80% dry matter) SWP is a sustainable substitute for fishmeal and soybean meal in animal feed, particularly for pigs, poultry, fish and ruminants. It promotes growth, feed efficiency and nutrient retention and has applications in human nutrition, cosmetics and pharmaceuticals. SWP processing for high-value proteins, chitin or oil supports the objectives of the circular economy and expands rural revenue streams. By encouraging small-scale processing and raising public awareness, this waste may be turned into a useful resource that would lessen its negative effects on the environment and help sustainable rural development in areas that produce silk.

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Developing Superior Fungal Biocontrol Strains through Molecular Biology Techniques

Introduction

Modern agriculture's dependence on synthetic chemicals poses environmental and health risks, driving interest in eco-friendly biological control using natural or introduced antagonists.Microbial biocontrol agents (BCAs), particularly fungal genera such as *Trichoderma*, *Coniothyrium*, *Gliocladium*, *Aspergillus*, *Penicillium*, and non-pathogenic *Fusarium*, have demonstrated considerable potential (Daranagama et al., 2020). Yet, their inconsistent performance under varied field conditions remains a significant challenge. Advances in biotechnology now enable the development of more robust fungal BCAs capable of maintaining efficacy under diverse and challenging environments.

Timeline of Fungal Biocontrol Agents

- ✓ **1874**: **W. Roberts** coined "antagonist" in microbiology; observed antagonism between bacteria and *Penicillium glaucum*.
- ✓ **1921**: **Hartley** first used microorganisms to control plant diseases (damping-off by *Pythium debaryanum*) in forest nurseries.
- ✓ **1928**: **A. Fleming** discovered penicillin, accelerating studies on microbial antagonists.
- ✓ **1931**: **Sanford & Broadfoot** first used the term "biological control" in plant pathology.
- ✓ **1932-1934**: **Weindling** demonstrated *Trichoderma lignorum* (*T. viride*) controlling plant pathogens via mycoparasitism.

Table 1: Advanced Omics Approaches in the Development of Fungal Biocontrol Agents (FBCAs)

Omics approach	Key Role in FBCA Development	Example
Genomics	Identifies genes for biocontrol traits, secondary metabolites, and mycoparasitism; aids in strain selection	Whole-genome sequencing of *Trichoderma asperellum* SM-12F1 revealed genes for plant growth promotion and pathogen suppression (Li et al., 2021)
Transcriptomics	Reveals actively expressed genes during interactions; elucidates regulatory pathways and enzymes	RNA-seq of *T. harzianum* T4 showed 2871 DEGs related to mycoparasitism against *B. cinerea* (Wang et al., 2023)
Proteomics	Identifies proteins/enzymes involved in pathogen suppression and induction of plant defense.	*T. atroviride* produced N-acetyl-β-D-glucosaminidase and endochitinase against *R. solani* (Grinyer et al., 2005)
Metagenomics	Explores uncultivable microbes; identifies novel biosynthetic genes; improves strain selection	Metagenomic analysis of endophytic microbes enabled discovery of potential biocontrol genes.

Fungi as biocontrol agents and the role of molecular approaches

Fungi serve as effective biocontrol agents against insect pests, plant diseases, nematodes, and weeds due to their target specificity, rapid reproduction, and ability to persist in the absence of a host. However, their inconsistent field performance under varying environmental conditions necessitates molecular and omics-based strategies to improve efficiency. Such approaches can elucidate interactions between beneficial fungi and pathogens and enable the development of engineered strains capable of detecting plant stress and conferring desirable traits (Ayaz et al., 2023).

Advanced Molecular Approaches for developing superior strains of fungal biocontrol agents

Advanced molecular and omics-based approaches such as genomics, transcriptomics, proteomics, secretomics, and metagenomics have revolutionized the ability to identify key genes, proteins, and metabolites that govern biocontrol efficacy (Fig. 1). These tools not only enable the selection and engineering of superior strains but also provide insights into the optimal conditions and timing for their application.

1. **Mutagenesis:** Random mutagenesis accelerates the generation of fungal variants using chemical agents such as NTG, EMS, MNNG, NaN_3, and HNO_2, or physical mutagens including UV, X-rays, and neutrons. For example, EMS-mutagenized *T. harzianum* exhibited 97–100% inhibition against several pathogens, and gamma radiation generated *T. harzianum* mutants with higher growth inhibition and colonization rates against multiple fungi.
2. **Protoplast fusion:** It enables intra-, interspecific, and intergeneric recombination to create superior hybrids by removing genetic incompatibilities. Fusants of *T. harzianum* and *T. viride* have shown enhanced chitinase,

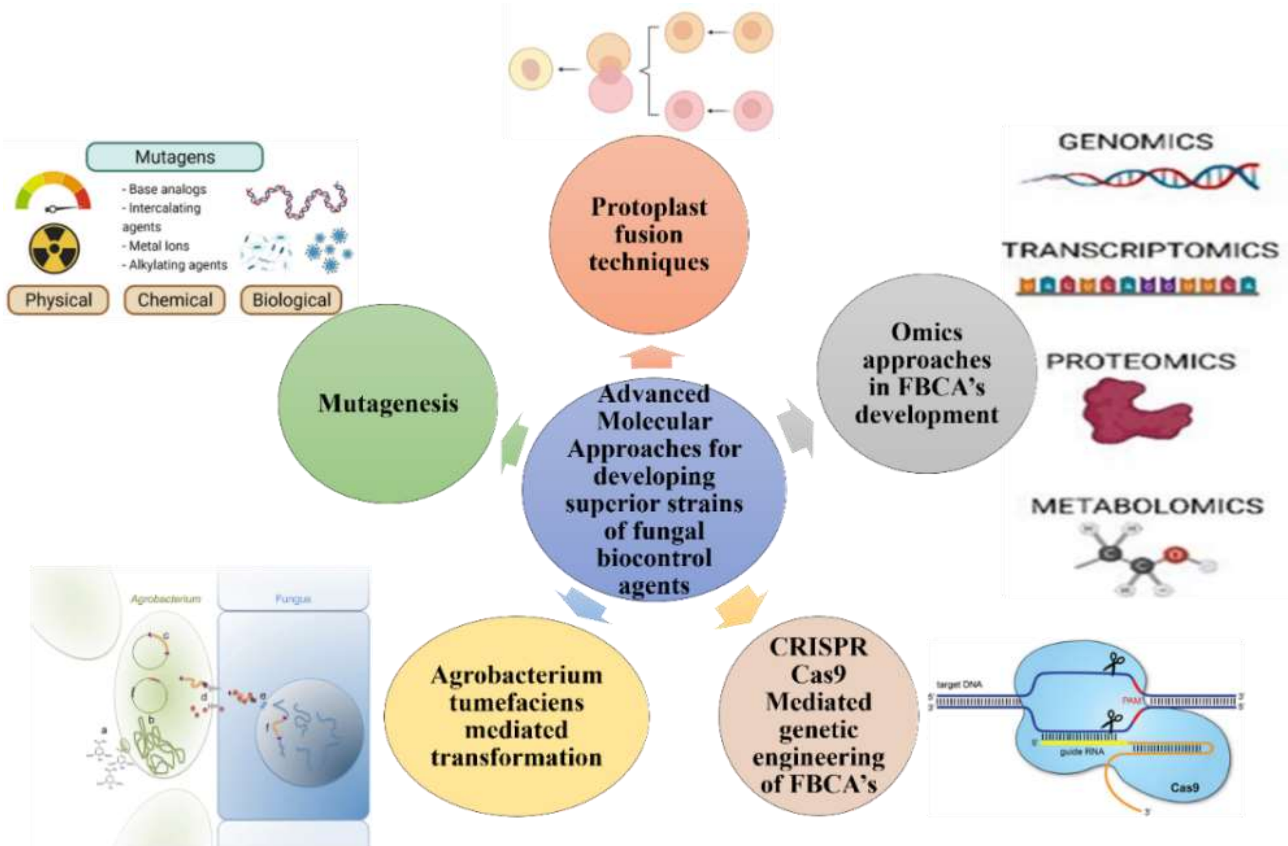

Fig. 1: Advanced molecular approaches for developing superior strains of fungal biocontrol agent

cellulase, β-1,3-glucanase, and protease activities.

3. **Agrobacterium tumefaciens-mediated transformation (ATMT):** This allows transfer of foreign genes into fungal genomes to enhance biocontrol traits. Using ATMT, overexpression of chitinase genes such as *ChiV* and *Chi67-1* in *T. harzianum* and *Clonostachys rosea* increased enzyme production, antifungal activity, and parasitic rates, whereas gene disruption decreased antagonism.
4. **CRISPR/Cas9**: It offers precise genome editing for knockouts, gene substitutions, and overexpression in fungi. Optimized systems have been developed for *Fusarium oxysporum* and *T. harzianum*, enabling targeted gene editing and marker-free mutant generation while retaining strain fitness.

Omics approaches in FBCA's development

Understanding the mechanisms of microbial biocontrol agents (MBCAs) is crucial for effective formulation and application. Omics approaches: genomics, transcriptomics, proteomics, secretomics, and metagenomics have greatly advanced this understanding (Table 1).

Conclusion and future prospectus

Omics and molecular approaches are advancing our understanding of FBCAs and enabling development of improved strains, but genetic manipulation remains early-stage and requires careful regulatory and environmental monitoring.

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The Role of Agricultural Finance in India's Rural Economy

Introduction

Imagine a small farmer in a village. The rains are late, seed prices have gone up, and there's no bank nearby. With no timely support, he borrows money from a local moneylender who charges very high interest. This situation is still common in many parts of rural India, where farming families struggle without proper access to finance.

Agriculture continues to be the backbone of India's rural economy, supporting nearly 60% of the population. But farmers often lack timely financial help — whether to buy seeds, repair equipment, or recover from crop losses. This is where **agricultural finance** plays a vital role.

What is Agricultural Finance?

Agricultural finance refers to the financial services designed to support farming and rural development. It includes the money farmers borrow, save, invest, or receive as assistance. These services may come from banks, cooperatives, government programs, or private institutions.

The aim is simple — to ensure that farmers have funds when they need them, whether for seeds, fertilizers, irrigation, labour, or to protect against crop failures.

Types of Agricultural Finance:

1. **Short-Term Credit** – For seasonal expenses such as seeds, fertilizers, pesticides, and irrigation.
2. **Medium-Term Credit** – For buying equipment like pumps, dairy animals, or small machinery.
3. **Long-Term Credit** – For big investments such as land, storage facilities, or orchards.
4. **Subsidies and Support Schemes** – Financial aid to reduce costs or encourage sustainable practices.
5. **Crop and Weather Insurance** – Protection against losses from drought, floods, or pests.

Agricultural finance is not only about credit; it is also about giving farmers the confidence to plan better and invest in their future.

Importance in Rural Development

Access to finance can transform villages. With timely loans, farmers can purchase higher-quality seeds, fertilizers, and tools, resulting in increased yields and incomes. It also reduces their dependence on informal lenders who trap them in debt.

Agricultural finance also supports activities like dairy, poultry, and Agro-based businesses. These activities create more jobs in rural areas, from storage and transportation to food processing. With better financial support, farmers adopt modern practices such as drip irrigation, solar pumps, and digital tools, leading to sustainable growth.

In short, finance empowers farmers not only to survive but to grow, diversify, and build a stronger rural economy.

Challenges Farmers Face

Despite progress, many farmers still struggle to access formal credit. Key challenges include:

- **Distance & Infrastructure:** Banks are often far from villages.
- **Delays in Processing:** Loan approvals can take weeks.
- **Complex Paperwork:** Many farmers lack land records or documents.
- **Financial Literacy:** Farmers may not fully understand formal credit options.
- **Bias in Lending:** Small and marginal farmers often face difficulty compared to larger landowners.

As a result, over 30% of rural households still depend on moneylenders, according to NABARD surveys.

Way Forward and Future Outlook

To build a stronger financial system for agriculture, India must focus on:

- Simplifying loan processes and paperwork.
- Promoting digital banking and fintech solutions.
- Increasing financial literacy in local languages.
- Designing climate-resilient finance to protect against climate change.

With innovations like mobile banking, Direct Benefit Transfers (DBT), and agri-fintech startups, the future of agricultural finance is becoming more inclusive and transparent.

For students, researchers, and future professionals in agriculture, the challenge is not only to understand these systems but also to improve them. By working with cooperatives, farmer groups, and digital tools, the next generation can ensure that finance truly reaches those who need it most.

Conclusion

Agricultural finance is more than just money. It is a **lifeline** that allows farmers to take risks, adopt new methods, and secure their livelihoods. A rural economy with strong financial support is one where farmers are empowered, communities are stronger, and agriculture remains sustainable for generations to come.

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Agriculture as a climate solution: Carbon Sequestration

Abstract

Crops, livestock, and food are frequently what come to mind when we think of farming. However, did you know that farms can be effective allies in the fight against climate change? In addition to contributing to greenhouse gas emissions, agriculture has the capacity to sequester carbon in vegetation and soils. Carbon sequestration is a process that has the potential to transform farms into organic climate warriors. Farmers can restore soil health, trap carbon, and make the world greener by implementing techniques like biochar, organic amendments, cover crops, agroforestry, and conservation tillage. Using examples from India and other countries, this article examines how agriculture can contribute to the climate solution in ways other than just producing food.

Introduction

Imagine that farmers are combating climate change in addition to producing food each time they plant a tree, improve their soil, or grow cover crops. Agriculture is at a turning point in a world beset by resource depletion, unpredictable rainfall, and rising temperatures. Although it is responsible for almost 25% of the world's greenhouse gas emissions, it also possesses the rare capacity to sequester carbon and securely store it in the soil.

Carbon sequestration is the name of this process, and it's not just a scientific term. It serves as a vital link between environmental and food security for our planet. Soils can act as carbon vaults with the correct farming techniques, storing more carbon than vegetation and the atmosphere.
This process is called carbon sequestration—and it is more than just a scientific term. It serves as a vital link between environmental and food security for our planet. Soils can store more carbon than the atmosphere and vegetation combined if they are farmed properly. How can we incorporate agriculture into the climate solution, is the question

How Agriculture Preserves Carbon

The basic process of photosynthesis is what drives carbon sequestration. A portion of the CO_2 that plants absorb from the atmosphere is channelled into their roots, where it is transformed into food. This carbon-rich material is incorporated into the soil when plants die. Large carbon reserves are accumulated over time by healthy soils, increasing fertility and lowering greenhouse gas emissions.
However, not all farming methods are created equal. While excessive tillage or fertilizer use in conventional farming frequently results in carbon emissions, sustainable farming practices reverse this trend by transforming farms into long- term carbon sinks.

Preservation Tillage:
Conservation tillage maintains soils rich in organic matter and stops carbon loss by reducing soil disturbance. For example, Punjabi farmers who used minimum tillage for wheat reported better soil moisture and lower diesel expenses.

Cover Cropping:
It's like leaving a treasure chest unlocked when you leave soil bare. In addition to providing the soil with organic matter and protection, cover crops also retain carbon that would otherwise leak into the atmosphere. In Madhya Pradesh, cover crops based on legumes have shown promise in raising soil fertility and lowering fertilizer requirements.
Crop Diversification and Rotation: Adding legumes or oilseeds to cereal rotation improves nutrient cycling and guarantees a steady supply of organic matter. According to a Gujarati study, adding pigeon peas to crop rotations increased soil organic carbon levels by almost 20% over a ten-year period.

Agroforestry:
Farm trees serve as carbon guardians in addition to offering shade and lumber. Arecanut based agroforestry systems in Karnataka provide farmers with financial and environmental advantages by storing up to 35 tonnes of carbon per hectare.

Natural Supplements:
In addition to increasing soil fertility, manure, compost, and green manures nourish the soil microbes that aid in carbon storage. Andhra Pradesh's Zero Budget Natural Farming (ZBNF) initiative has shown increased soil organic carbon while reducing farmers' input costs.

Better Control of Grazing:
When grazing is properly controlled, grasslands can be effective carbon sinks. In Rajasthan, community pasture management initiatives involving rotational grazing have improved soil quality and bolstered rural economies.

Technology of Biochar:
Crop residues can be converted into biochar, a material that resembles charcoal, which locks carbon in the soil for hundreds of years. According to Haryana pilot projects, adding biochar increases soil fertility and water-holding capacity while also reducing stubble burning.

Why It Matters: Advantages That Go Beyond Carbon

Building stronger, more resilient farms is the goal of carbon sequestration, not merely cutting emissions.

Climate change is slowed down for the planet when there is less CO_2 in the atmosphere.

For the soil Fertile, healthier soils are the result of richer organic matter.

Higher yields, more fertile land, and the possibility of earning money from carbon credits are all benefits for farmer.

For society —a safer future, a stable food supply, and healthier ecosystems.

Changing agriculture from contributing to the climate crisis to becoming a climate hero is a win-win approach.

Challenges
Obstacles in the Way Of course, there are obstacles in the way. It is difficult to quantify the actual amount of carbon stored by soils. Without financial assistance or legislative incentives, farmers might be reluctant to implement new practices. Furthermore, if land is disturbed or severe weather conditions occur, stored carbon may be released once more. But rather than deterring us, these difficulties ought to spur creativity. These obstacles can be removed and broad adoption promoted with the aid of stronger regulations, carbon credit markets, and awareness initiatives.

The Global and Indian Perspective

The "4 per 1000" campaign, which was introduced at COP21 in Paris, encourages farmers worldwide to raise soil carbon stocks by 0.4% annually. A large portion of humanity's yearly emissions could be offset by this slight increase. The average soil organic carbon (SOC) content in India is between 0.3 and 0.6%, which is significantly less than the global average. This points to a huge opportunity. Practices that improve SOC are encouraged by government programs such as the National Agroforestry Policy, Paramparagat Krishi Vikas Yojana (PKVY), and the National Mission for Sustainable Agriculture (NMSA). With the help of ZBNF, states like Andhra Pradesh hope to convert 6 million farmers to natural farming, potentially making it one of the biggest carbon sequestration initiatives globally.

Given India's goal of reaching Net Zero by 2070, agricultural carbon sequestration may be crucial in determining the course of the nation's climate.

Conclusion

The goal of agriculture has always been to provide food for people. But it's also about healing the planet in today's world. Farmers can lessen the effects of climate change and store atmospheric carbon by implementing climate-smart practices that transform their soils into carbon banks.

The message is unambiguous: any farmer, farm, or field can become a climate warrior. Harvesting food is no longer the only goal of agriculture; it is now also about harvesting hope for coming generations.

One seed, one tree, and one handful of soil at a time, farming has the potential to be the most potent remedy for climate change in the world if it is properly cultivated.

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Different Methods of Fertilizer Application in Bihar

Abstract:

This article explores the different ways farmers in Bihar apply fertilizers to their fields. Situated in the fertile Indo-Gangetic plains, Bihar's farmers rely on both age-old traditions and modern techniques to keep their soils productive. From simple methods like broadcasting and using animal manure, to more precise approaches such as row placement and fertigation, each practice reflects a balance between resources, crop needs, and farmer knowledge. While traditional techniques are easy and affordable, modern methods promise higher efficiency but demand better infrastructure and awareness. Together, these practices show how Bihar's farmers are constantly adapting to improve crop yield, soil health, and long-term sustainability

Introduction:

Agriculture is at the heart of Bihar's economy. For many rural families, crops like rice, wheat, and maize are not just food but a source of livelihood. To maintain healthy soils and good harvests, farmers depend heavily on fertilizers.

Over the years, farmers in Bihar have adopted a variety of fertilizer application methods. Some of these, such as broadcasting or applying cow dung, have been passed down through generations. Others, like fertigation, are relatively new and reflect the influence of technology and irrigation facilities. Every method comes with its own benefits and challenges, but together they highlight how farmers are blending tradition with innovation to meet the needs of their fields.

Common Methods of Fertilizer Application:

1. Broadcasting: This is perhaps the simplest and most widely used method. Farmers spread fertilizers evenly across the field, either before planting or after sowing. It saves time and labour, but often nutrients get washed away or lost in the soil, making it less efficient.

2. Placement: Here, fertilizers are placed close to the seed or root zone. This ensures crops get nutrients right where they need them most. In Bihar, it's especially common in maize and wheat cultivation. While it requires more effort than broadcasting, it reduces wastage and helps crops grow better.

3. Top Dressing: This method is about timing. After the crop has sprouted, farmers apply nitrogen-rich fertilizers (mainly urea) to boost growth during critical stages. In Bihar, top dressing is widely practiced for rice and wheat. The challenge, however, is that its success often depends on timely rain or irrigation.

4. Organic Manure

For generations, farmers have relied on cow dung, goat manure, compost, and even green manure crops. Organic manures enrich the soil, improve water retention, and enhance long-term fertility. They're eco-friendly and affordable, but preparing and applying them can be labor-intensive.

5. Fertigation (An Emerging Practice)

In areas where irrigation systems exist, fertilizers are mixed with water and applied directly through irrigation. Though still limited in Bihar, fertigation delivers nutrients more precisely and can significantly increase yields. The main barrier is access to technology and proper irrigation facilities.

Advantages of Different Methods:

- Better nutrient supply: Placement and fertigation make fertilizers more effective.
- Sustainability: Organic manures keep the soil healthy and improve its structure.
- Low cost: Broadcasting and manure use are budget-friendly options for small farmers.
- Flexibility: Farmers can choose methods based on their resources, crops, and water availability.

Disadvantages:

- Nutrient losses: Broadcasting often leads to runoff and leaching.
- Labor intensive: Applying organic manure or placing fertilizers takes time and effort.
- Dependence on rain: Top dressing works best only with proper rainfall or irrigation.
- Limited access: Advanced methods like fertigation are mainly used by progressive farmers.
- Uneven results: Variations in soil and water conditions can affect fertilizer uptake.

Conclusion:

The way fertilizers are applied in Bihar tells the story of farmers balancing tradition and innovation. Methods like broadcasting and organic manure remain popular because they're simple and affordable, while newer techniques like placement and fertigation show promise for improving efficiency and sustainability. For Bihar to boost productivity and protect its soils, farmers need better access to modern techniques, reliable irrigation, and awareness about balanced fertilizer use. With the right support, Bihar's fields can remain fertile and productive for generations to come.

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15 Types of Red Flowers That Will Look Perfect In Your Flower Garden

Introduction

Whether this is your first season planning a garden or you're an experienced gardener who wants to add some bold accents to your flower bed, you can't go wrong with red. It's widely regarded as the color of passion, and pops vibrantly against the greenery in a garden. You can find glorious crimson hues in bulbs, annuals, and perennials, as noted by Pro Flowers.

We've rounded up 15 types of red flowers that will look perfect in your garden. Even if you don't have a garden and instead use planters on your apartment balcony, these gorgeous flowers will work in just about any setting. Because red demands a lot of attention, you can always start with it in small doses to see how it pairs with other colors that are already present in your flower bed, or choose one area to design a dramatic focal point.

1. Poppy

The poppy (scientific name papaver) comes in many different colors, but it is most widely recognized — and most popular — in its red hue. Historically, they're known as the flower of remembrance, because they're said to pop up on battlefields after the fight has ended. Both real and artificial versions are often given out during memorial services.

If you want to plant them in your garden, Gardening Know How says they're easy to grow. You can start them from seeds, divide an existing plant, or buy them from your local garden center. Just make sure not to overwater them, as they like well-drained soil. Pro Flowers warns that beginner gardeners often kill them by overwatering.

1. Dahlia

If you want to bring enormous blooms and a dramatic flair to your garden, choose the dahlia (scientific name dahlia). Their flowers can grow to be an entire foot across — a size that earned them the nickname "dinner plate dahlias," according to Longfield Gardens.

Gardening Know How explains that success with your dahlias begins by selecting healthy tubers; this means the outside should be firm to the touch and free of mold or soft spots. Wait to plant them until any chance of frost has passed, and choose an area that gets plenty of full sun. Dahlias do well in moist, well-draining soil.

If your goal is giant blooms, set up support stakes at the time of planting to support them. Additionally, using more fertilizer should help your blooms increase in size. Just look up the details for your particular variety to know how much to use.

2. Rose

One hardly needs to introduce the rose (scientific name rosa) since it's arguably one of the most popular flowers in the world. If you want to try growing roses, all the complicated explanations can be overwhelming.

Gardening Know How says that rose bushes need at least six hours of sun per day, in soil that is moist but well-draining. Additionally, roses can be bought in a couple of ways. The first is "bare root," which means they're packaged without soil and their roots are wrapped in plastic (via Gardening Know How). The other is potted and ready to move into the ground without additional prep work. Both varieties should be planted in the spring.

Roses need consistent watering to thrive. During their growing season, Gardening Know How suggests at least an inch of water weekly. Water directly at the roots to protect the roses from debilitating fungal diseases.

3. Plume Celosia

While there are several different varieties of celosia, plume celosia (scientific name celosia plumosa) comes in a fiery color palette of red, yellow, orange, and pink. It's a whimsical, easy-to-grow annual that adds interest to any flower bed or planter. If you're looking for a colorful flower that's low maintenance and blooms throughout the whole summer, you can't go wrong with red celosia.

My Garden Life suggests planting in full sun, as these flowers can handle scorching heat like a champ. As mentioned, because they're low maintenance, you just need to watch out for overwatering. Red celosia are susceptible to root rot if you give them too much H_2O, so keep the soil moist, but only just so. If the leaves begin to turn yellow or the plant loses its upright appearance and begins to wilt, these are telltale signs of overwatering.

4. Hibiscus

Want to bring a tropical feel to your garden? Hibiscus (scientific name hibiscus rosa-sinensis) should be tops on your list. There are two types: hardy and tropical. Depending on your gardening desires and zone, you should carefully research before deciding which type of hibiscus is right for you.

For a tropical hibiscus, plant it in a container so you can bring it inside over the winter or else it won't survive. However, hardy hibiscus can survive in the ground through the winter, says Gardening Know How. Just trim it down to a height of around five inches before the winter, and you should see it coming back at the beginning of the following summer.

All varieties of hibiscus need lots of sunlight and consistently moist, well-draining soil. You never want the soil to get dry. Gardening Know How also suggests using an all-purpose fertilizer to maximize blooms and strong growth.

5. Begonia

Although there are many varieties of begonia (scientific name begonia), the most recognized are wax begonias and tuberous begonias. Both are annuals and both are excellent performers in pots, window boxes, and hanging baskets. These low maintenance flowers bloom all summer long, plus they self-clean, so no deadheading is required.

6. Geranium

Enjoyed for their bright colors, pleasant scent, and low maintenance care, geraniums (scientific name pelargonium) are a classic choice among gardeners. When grown outside, they're annuals, but you can overwinter them inside. They're also a popular choice for growing inside year round, as a companion to other houseplants.

Gardening Know How says you should make sure your geraniums get at least six hours of sunlight, and don't plant them until any chance of frost has passed, as they don't fare well in cold temperatures. For watering, you'll want to keep the soil consistently moist. If you're planting geraniums in pots, they may require daily watering on hotter days. To encourage continuous blooms, deadhead spent blooms as needed

7. Azalea

A perennial shrub bursting with beautiful, long-lasting blooms, azaleas (scientific name rhododendron) are a popular choice for any garden or landscape that needs a boost of color.

Most azaleas prefer partial shade and can be scorched by full sun. However, some varieties do well in direct sunlight. When it comes to size, check the care card for your particular plant to ensure you account for enough space. According to Pennington Seeds, some varieties can grow to a whopping height of 20 feet, though dwarf varieties (reaching heights of only a few feet) are more common.

Azaleas need acidic soil in order to bloom proficiently. If you're not sure about your soil's acidity, you can perform a simple soil test and then amend the pH as needed. Because azaleas have shallow root systems, this means the soil needs to be moist and well-draining.

8. Dianthus

While most varieties are perennial, some types of dianthus (scientific name dianthus) can be annuals or biennials. They bloom in shades of pink, red, and white. Whether you want one that mounds, trails, or grows tall, Garden Design promises that there's a perfect dianthus to fit your garden.

Choose a location that receives a minimum of partial sun, but full sunlight is preferable to guarantee the best blooms. Additionally, dianthus doesn't fare well in shady areas, according to Garden Design. Also, make sure the soil is moist and well-draining. Certain varieties of dianthus prefer more acidic soil, so check the care tag of the variety to choose in case the soil needs to be amended.

Garden Design encourages deadheading your dianthus. If your plant is a few years old and a dead spot forms in the middle, that's a telltale sign it's time to divide it.

9. Peony

Even people with very little flower knowledge are likely to recognize the layered, prolific blooms of the peony (scientific name paeonia). Though the perennial bush has a short bloom time of just a couple of weeks, their longevity is unparalleled. According to Gardener's Supply Company they can live over 100 years if planted correctly.

Plant your peonies where they'll receive full sunlight. It's important not to crowd them too close together, as they need proper air circulation to prevent a fungal disease called botrytis, says Gardener's Supply Company. Once your peony is established, you don't need to worry about a strict watering schedule — just make sure the soil drains well.

Because peony blooms are so large, it's important to provide support for them. Set up stakes or cages early in the spring to minimize damage to the plant.

10. Petunia

Petunias (scientific name petunia) are lovable annuals. They're easy to grow, come in an incredible array of colors and patterns — even stripes and polka dots — so you can choose a variety that perfectly suits your aesthetic. They can trail, mound, or be compact in shape. Petunias give you prolific flowers throughout the entire season, though most varieties do require some deadheading in order to maximize the never-ending blooms and keep the plant looking healthy.

Garden Design says that you should plant petunias in full sun, even if you're putting them in containers. They have a shallow root system, so regular watering is a must. If there's a particularly hot and dry stretch, the petunias will need daily watering.

11. Coneflower

The perennial coneflower (scientific name echinacea) is beloved by pollinators. It's easy to grow, low-maintenance, and has been used in herbal medicinal remedies for hundreds of years. While coneflower is commonly seen in shades of pink or purple, you can find it in a striking shade of red that will look perfect in your garden.

The Old Farmer's Almanac says that coneflowers can grow up to four feet in height, so plan for this vertical growth accordingly. Once they're established, they'll self-sow, which means you'll have effortless blooms to enjoy for years to come.

Choose a location with full sunlight and well-draining soil for coneflower. They're drought-resistant, but Garden Design suggests watering about an inch weekly. If your flowers are on the small side, you can add a bit of compost to the soil and around the plant for additional nourishment.

12. Chrysanthemum

More commonly known by the shortened "mums," chrysanthemums (scientific name chrysanthemum) signal the arrival of autumn, come in tons of varieties, and bloom from late summer into the fall. They can be annuals or perennials, though a hardy variety must be chosen to withstand the winter.

Mums are low-maintenance as long as their basic needs are met, says Garden Design. This means they want full sun, nutrient-rich soil, proper air circulation (so don't overcrowd them), and good drainage. One final piece of essential care for mums is "pinching." Gardening Know How explains that this practice translates to more blooms. You pinch back the mums (yes, just pinch with your fingers) when new growth is around six inches, and make sure to remove the stem that's above the second set of leaves.

13. Verbena

If you think the hot, dry weather in your area means you can't have beautiful flowers in the garden, let's introduce you to verbena (scientific name verbena.) It's highly tolerant of heat and drought, and comes in annual and perennial varieties. Verbena also thrives in hanging baskets, containers, or the garden bed.

Gardening Know How calls verbena a "tough specimen," and says it needs to be placed somewhere that gets at least eight hours of sun per day. It's not a fussy flower and doesn't mind poor soil quality, but you want to make sure the soil still drains well. Verbena roots do not like being soggy; even though it can go a while without water, Gardening Know How says a weekly watering of an inch will give you better blooms.

14. Ranunculus

With layers of ultra-thin petals, ranunculus (scientific name ranunculus) flowers are a favorite choice for cut flowers and are often used in wedding bouquets. The perennials come in a rainbow of colors, with their deep red shade being especially appealing.

According to Breck's Seeds, ranunculus are grown from corms. They should be planted in the fall for most zones, but you can plant them in early spring if your area is prone to severe winters. Corms require a bit of prep work, and you'll want to read through the steps carefully to ensure they thrive once they're planted.

Breck's Seeds says ranunculus need lots of sun and rich, well-draining soil. Place the "claw" part of the corms down as you plant them, and give a good watering once they're in the ground. Apply a layer of mulch to ensure they retain moisture during this early growth period.

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Seeds of Change: Women Shaping Agriculture

ABSTRACT:

Women sustain fields, families, and food systems with their tireless efforts. When given equal access to resources, they transform agriculture into a driver of prosperity. They are the true seeds of change, nurturing a sustainable and inclusive future.

Keywords: Rural women empowerment , Sustainable Agriculture, Women and Livelihood.

INTRODUCTION:

Agriculture has always been the backbone of human survival, providing food, raw materials, and livelihoods for billions, and at its core stand women whose contributions often go unnoticed. For centuries, they have balanced roles as cultivators, livestock managers, caretakers, and household providers, silently sustaining both farms and families. Despite forming the backbone of rural economies, women farmers remain marginalized with limited access to land, credit, technology, and recognition in policies and programs. Yet, in the face of global challenges such as climate change and food insecurity, their role is becoming more vital than ever. Women today are moving beyond traditional tasks to embrace innovation, climate-smart practices, entrepreneurship, and leadership in farming communities. Their resilience, creativity, and adaptability are transforming agriculture into a more inclusive and sustainable sector. By empowering them with education, technology, resources, and equal opportunities, we can unlock their full potential. Women are not merely participants in agriculture they are the true seeds of change shaping its future.

An estimated two-thirds of the world's poor livestock keepers—around 400 million individuals—are women (Thornton et al., 2002). Women often take a leading role in managing poultry (FAO, 1998; Guèye, 2000; Tung, 2005), dairy production (Okali & Mims, 1998; Tangka, Jabbar, & Shapiro, 2000), and in caring for other animals that are raised and maintained within the household setting.The position of women in society has transformed considerably over time, and agriculture has been a central part of this change.

In developing regions especially, women have long been essential to agricultural production, though their contributions have frequently been underestimated and overlooked. In recent years, however, there has been growing acknowledgment of their role and the potential they hold for advancing agricultural growth. Research demonstrates that strengthening women's participation in agriculture can increase productivity, improve food security, and reduce poverty levels (Kumar et al., 2020).

A primary role of women in the agricultural sector is that of farmers and laborers. They are directly involved in cultivating crops, rearing livestock, and supporting other farming activities. Through their labor, expertise, and knowledge, they play a vital part in the sector's development and productivity. Moreover, women's involvement in decision-making and farm management has been shown to positively influence both productivity and profitability (Doss, 2021).Beyond farming activities, women also contribute as entrepreneurs and business leaders. They participate in agribusiness ventures that include processing, value addition, packaging, and marketing of agricultural goods. By engaging in these activities, women strengthen agricultural value chains and support rural development. Furthermore, studies point out that women's entrepreneurship has the potential to drive innovation and promote sustainable practices in agriculture (Maestre et al., 2019). Encouraging and supporting such initiatives can expand income opportunities, create jobs, and foster overall growth of the sector.

- **Women at the Core of Agriculture :** Women have long been central to farming, balancing roles as cultivators, livestock managers, and caregivers, sustaining households and rural economies.

- **Barriers and Gender Gaps :** Despite their numbers, they face unequal access to land, credit, and technology, limiting potential.

- **Evolving Roles in Agriculture:** Women now adopt climate-smart practices, take leadership, and enter agri-entrepreneurship.

"Women farmers are the roots of agriculture. Through their hardwork (Trunk), they branch into livestock, entrepreneurship, and decision making, ultimately bearing fruits of food security, income, education, and sustainability".

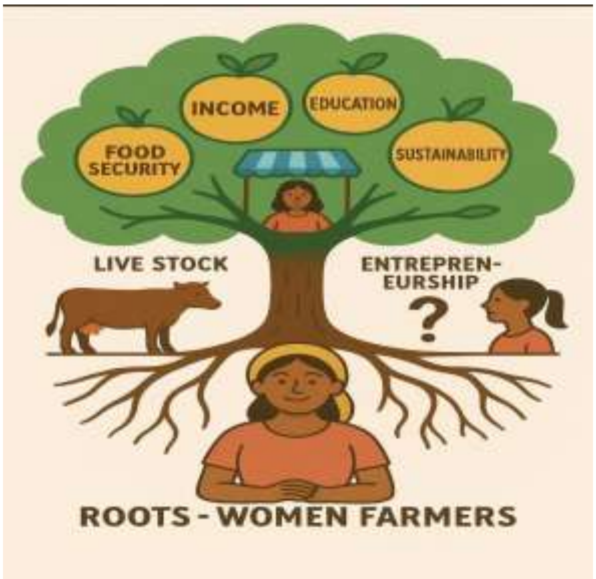

Figure-1 . From Roots To Fruits : Empowering Women In Shaping Agriculture's Future (Source :N.B.R.Pravallika)

- **Contribution to Food Security and Productivity:** Empowerment boosts yields, nutrition, and poverty reduction.
- **Women as Agricultural Entrepreneurs:** They add value through processing, marketing, and innovation.

- **Path to an Inclusive Future:** Education, resources, and supportive policies ensure sustainable, inclusive growth.

CONCLUSION:

Women stand as the backbone of agriculture, fostering productivity, sustainability, and food security. Even with limited access to land, finance, and modern technology, they continue to transform farming through resilience and innovation. Acknowledging and supporting their role is essential for building inclusive rural development. Providing equal opportunities will enhance livelihoods and help combat hunger. Indeed, women are the true seeds of change shaping the future of farming.

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Bauhinia vahlii: A Climber with Medicinal, Cultural and Economic value

Scientific name: *Bauhinia vahlii* Wight & Arn.
Family: Fabaceae
Chromosome Number: 2n= 28

Introduction

Bauhinia vahlii Wight & Arn. commonly known as Maloo creeper or Toor is a woody climber of Fabaceae family. The species takes the support of nearby trees to grow highand may rise upto 15-30 meters depending upon the size of the supporting trees in the forest. It is commonly known as "camel's paw", because of the characteristic shape of its leaves. The species is well established as medicinal woody climber and its various parts have medicinal uses such as leaves are used as demulcent, edible seed as tonic, bark for extracting tannins and leaves are even used as fodder and commercially used as donas and pattals. The seeds can be eaten raw or fried or cooked as pulse. It is well distributed in the foothills of the Himalayas, including the Shivalik ranges of Punjab, Himachal Pradesh and Uttarakhand ranging upto 1200 metres above mean sea level. It spreads from India to Africa, South America, Nepal and Pakistan and also found in Assam, Central India, Bihar, Eastern and Western Ghats. In Punjab, it is well distributed in Pathankot, Hoshiarpur and Ropar districts. In central Punjab plains (Bathinda, Ludhiana, etc.), it is absent naturally, but it can be planted as an ornamental or soil conservation in various agroforestry systems.

Toor is a huge climber with recently evidenced antioxidant, anti-hyperglycemic and anti-inflammatory effects. It can be differentiated from other *Bauhinia* species by its climbing growth; it's very large camel's foot shaped leaves.

Climate and Soil

Bauhinia vahlii is well distributed in the foothills of the Himalayas, ranging about 250m to 1200 metres above mean sea level; it is considered as the formidable enemy of trees. It is not particular to any soil type as they can grow well in alkaline rocky soil and acidic soil but in the well-drained condition.

Botanical Description

The species' main stem is characterized by hard, solid and cylindrical woody liana with thick brown cork showing longitudinal fissures and transverse cracks.

It grows obliquely, vertically or horizontally for about a few meters length and later taking the support on the nearby woody species and trees.The white-coloured flowers of this species which are arranged as corymbose terminal racemes; begin to appear during April and may continue upto June thereby the entomophilous pollination takes place with the anthesis of floral buds.

The type of the fruit of this species is a long flat woody pod bearing fine rusty hair and normally 2-3 pods are formed from each inflorescence. Seeds are flat, dark brown, polished and 2.5 mm in diameter.

Propagation

Toor is mainly propagated through seeds.

Micro Propagation of *Bauhinia vahlii*

For the micro propagation of *Bauhinia vahlii*, the Murashige and Skoog medium with 1.0 M thidiazuron method is proved to be the most effective for the shoot proliferation and shoot multiplication.

Regeneration of *Bauhinia vahlii*

To regenerate in vitro of a mature leguminous liana (*Bauhinia vahlii* Wight and Arn), Browning was the major obstacle in the establishment of cultures. However, the combination of thidiazuron and kinetin is proved to be effective for increasing the number of shoots significantly up to four successive subculture cycles.

Benefits of *Bauhinia vahlii* Wight & Arn.

A. Pharmacological benefits:

1. Anti-inflammatory: An anti-inflammatory or antiphologistic is the treatment that reduces inflammation or swelling and pain. They act as an analgesic or pain killers. The petroleum ether, chloroform, and ethanol extract of the dried whole plant material of *Bauhinia vahlii* Wight & Arn was found having anti-inflammatory effect induced by paw edema at the dose of 353 mg/kg comparable to standard Ibuprofen

2. Anti-Diabetic: Anti-diabetic substances are used in the treatment of diabetes mellitus to control glucose levels in the blood. The ethanolic and chloroform extract of *Bauhinia vahlii* Wight & Arn is useful in the reduction of blood sugar level from 2 to 24 h in a progressive manner.

3. Antimicrobial: Antimicrobials are the therapeutic substances used to prevent or treat infections. They include antiseptics, antibiotics, antivirals or antifungals. The antimicrobial potency of the stem bark of *Bauhinia vahlii* Wight & Arn has been studied using the petroleum ether, benzene, chloroform and ethanol extract against the gram-positive and gram-negative bacteria.

4. Antioxidant: Antioxidants are the substances that protect cells from the damage caused by the free radicals. The seeds of *Bauhinia vahlii* Wight & Arn have the antioxidant potential in them.

B. Ethno-pharmacological Uses: The roots are used for the pulmonary tuberculosis and root juice used in dysentery. In some places the roots of *Bauhinia vahlii* Wight & Arn is used as toothbrush to cure the pyorrhea. Leaves used in the treatment of abrasions and fruits used for the treatment of anti-fertility in women. Bark is useful for skin disease and pod taken orally for the treatment of diarrhea.

C. Classical Uses: Toor leaf is an important Non- Timber Forest (NTFP) Product of central and southern Orissa, India. The leaf is used by the local grocery shopkeepers and petty hotels as plates and packaging material. Fibers obtained from stem bark used to make the ropes. In the local market it is more precious than the Sal leaf. It is of more socio-economic importance in the life of tribal people as the ripened, fried and roasted seeds are eaten by the tribal people and leaves are used to eat meals rather than using plates. Serving meals on leaves is regarded as pure and good practice during the marriages and death ceremonies, free meals offered during religious festivals and community feasts.

D. Commercial Production and economic analysis: In the survey area of Paderu forest division of Andhra Pradesh, India abundant (*Bahunia vahlii* Wight & Arn) mohual leaves can be harvested almost throughout the year. The people in this area used to sell Mohual leaves without value addition at Rs. 5 for a bundle of 100 leaves. The forest department has since intervened and imparted training to make leaf plates with the help of compressor machine with a value of about Rs. 50,000. The incremental cost benefit of this technological intervention indicates that if an average a person can make one unit/bundle per day he / she will earn Rs. 60 (incremental benefit Rs. 30 + labour charges Rs. 30). The same task can be also performed by a self-help group consisting of four members and one machine. This would provide sufficient work per day for all four members, enabling the group to earn Rs 240 per day. However, assuming in a year there would be maximum of 200 working days then the total incremental benefit would be (Rs. 30 x 4 x 200) Rs. 24,000 p.a. assuming the venture lasts for 10 years, the pay-back period of the venture would be 2 years and 4 months. The NPV of the project at a 10 % discount rate is Rs. 97470/- and at a 15 % discount rate is Rs. 70450/- and IRR is 46 %, both of which are very positive financial returns on the initial investment. If four people contribute Rs. 12,500 each and take up the venture they will receive Rs. 6000 per annum for ten years in addition to each member getting employment for 200 days each year. All above inferences are made assuming that there would be market available for the total output of 800 units (200 units x 4 persons) p.a., but it is recognized that this might not be realistic. In many cases the main problem facing rural enterprises is availability of a market for finished products. Therefore, the developmental governmental agencies and NGOs, should not only impart training to add value to the local resources and interventional investment through microfinance but also to provide the market linkages for the sale of products. Its fibers are used in thatching, binding bidi leaves, making fences and roofing and are collected from Bihar and Orissa.

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Alternative Approaches for Alleviation of Reproductive Problems in Bovines

Abstract

Reproductive disorders in bovines significantly impact livestock productivity and farm economics. While conventional veterinary treatments are widely practiced, alternative approaches such as herbal medicine, acupuncture, homeopathy, and nutritional therapy are gaining attention for their holistic benefits. This article explores various non-conventional methods for managing reproductive problems in bovines, including the use of ethno-veterinary practices, Ayurveda, and environmental management. These approaches, when used alongside good husbandry, can improve fertility, reduce disease recurrence, and promote sustainable livestock care.

Introduction

Reproductive efficiency is a key determinant of productivity in bovine farming. Disorders such as anestrus, repeat breeding, retained placenta, metritis and endometritis are common challenges that lead to economic losses and reduced herd performance. While modern veterinary medicine provides effective solutions, it often involves synthetic hormones and antibiotics, which can have side effects and lead to drug residues in animal products. As a result, there is growing interest in alternative treatment methods that are natural, cost-effective, and environmentally sustainable. These alternative methods can enhance reproductive health, especially when used alongside good management and nutrition practices. These include herbal remedies, acupuncture, homeopathy, Ayurvedic formulations, and nutritional interventions. Integrating these alternative approaches into bovine reproductive health management can support physiological balance, enhance fertility, and improve overall herd health, especially in resource-limited settings.

One of the most widely used alternative systems is **herbal and ethno-veterinary medicine**, which relies on locally available medicinal plants and traditional knowledge. Herbs such as *Ashwagandha* (*Withania somnifera*) and *Shatavari* (*Asparagus racemosus*) are known to support hormonal balance, enhance fertility, and act as uterine tonics. Plants like *Garlic* (*Allium sativum*) and *Neem* (*Azadirachta indica*) have antimicrobial properties and are used to treat uterine infections and aid in uterine cleansing. These remedies are especially valuable in rural areas where access to conventional veterinary care may be limited.

Another promising approach is **acupuncture and acupressure**, which involves stimulating specific points on the animal's body to regulate internal functions. In bovines, these techniques have been used effectively to address reproductive disorders such as anestrus, ovarian cysts, and retained placenta. Acupuncture works by improving blood flow to reproductive organs, balancing hormones, and reducing stress, thereby supporting reproductive function naturally. This method requires a trained practitioner but has shown encouraging results in field studies. A report demonstrated that stimulation of acupoints such as GV20, BL23, and SP6 can activate the hypothalamic-pituitary-gonadal (HPG) axis in cattle, potentially improving ovarian activity. This approach has shown effectiveness in cases of anestrus, ovarian cysts, and silent heat.

Another report documented improved estrus signs and ovulation rates in dairy cows treated with electro-acupuncture on specific reproductive acupoints. The therapy helped to normalize serum progesterone and estrogen levels, leading to a better conception rate.

Acupressure, a similar technique using manual pressure instead of needles, is being practiced increasingly in rural areas by trained livestock handlers. While more evidence is needed for widespread adoption, the non-pharmacological nature of these methods makes them attractive for organic and sustainable dairy systems.

Homeopathy is also used by some farmers and holistic veterinarians to address subclinical and chronic reproductive issues. Remedies such as *Sepia* are indicated for uterine weakness and infertility, while *Pulsatilla* is commonly used for delayed or suppressed estrus, particularly in young heifers. Though scientific evidence supporting homeopathy is limited, it remains popular in organic and alternative livestock systems due to its non-invasive nature and lack of drug residues.

Ayurveda and Panchagavya therapy offer another traditional approach to managing reproductive issues. Panchagavya, literally five cow products, is traditionally made by blending and fermenting the five key items such as gomutra (urine), gomaya (dung), dugdha (milk), dadhi (curd), and ghrita (ghee).

Fermentation is typically carried out in shaded, clean containers over several days or weeks, with regular agitation. This process enhances the mixture's microbial and enzymatic activity, believed to boost its medicinal and agricultural efficacy.

Approach	Key Elements	Reported Effects
Herbal/Ethno-veterinary	Shatavari, Ashwagandha, Neem, Garlic	Improved estrus, reduced infections, hormonal balance
Acupuncture	GV20, SP6, BL23 points	Restored cyclicity, treated anestrus and cysts
Homeopathy	Sepia, Pulsatilla, Calcarea carb	Improved conception, regulated estrus
Ayurveda/Panchagavya	Panchagavya, Garbhapal Ras	Enhanced fertility, immune modulation, uterine cleansing

In Ayurvedic and ethno-veterinary traditions, Panchagavya is considered a bio-elixir with diverse uses. When administered orally, it's said to boost immunity, improve digestion, enhance milk production, support fertility, and alleviate ailments like mastitis or retained placenta. It also improves soil fertility, enhances plant growth, serves as a biopesticide, and promotes crop yield and quality. Beyond therapy, it's used in Vedic rituals for purification, spiritual cleansing, and healing practices.

Nutritional therapy plays a vital role in supporting reproductive health. Many reproductive problems stem from mineral and vitamin deficiencies, especially of selenium, zinc, copper, and vitamins A and E. Natural supplements such as seaweed, moringa leaf powder, and flaxseed are rich in essential nutrients and fatty acids that aid hormonal regulation and reproductive organ function. Ensuring a balanced diet tailored to the animal's physiological needs can significantly reduce reproductive issues.

Maintaining a healthy gut microbiome through the use of probiotics and fermented feeds also contributes to reproductive well-being. Probiotics like yeast culture and lactobacillus improve digestion and nutrient absorption, which indirectly supports hormonal health and fertility.

Finally, proper environmental and stress management is critical. Stress, caused by factors such as heat, overcrowding, or poor handling, can disrupt hormonal cycles and lead to problems like anestrus. Providing adequate shade, ventilation, and minimizing handling stress are essential steps toward improving reproductive outcomes in bovines.

Conclusion

Alternative treatment approaches offer promising support for managing reproductive problems in bovines. Herbal and ethno-veterinary practices, acupuncture, homeopathy, and dietary interventions provide natural, holistic options that can complement or, in some cases, reduce reliance on conventional veterinary treatments. While many of these methods require further scientific validation, their growing use in traditional and organic livestock systems highlights their potential. For optimal outcomes, these treatments should be used in conjunction with sound animal husbandry, proper nutrition, and under the guidance of trained professionals. With increasing focus on sustainable and residue-free livestock production, alternative therapies present a viable path forward in bovine reproductive management.

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Seed Treatment and Its Importance in Agriculture

Abstract

Seed treatment is an essential practice in modern agriculture, aimed at safeguarding seed quality, enhancing germination, and protecting seedlings against pests and diseases. It involves chemical, biological, and physical methods that improve seed vigor, minimize yield losses, and promote sustainable crop production. This article discusses the definition, types, and methods of seed treatment, along with their advantages, safety measures, and future scope. Special emphasis is given to chemical and biological treatments, pre- and mid-storage treatments, and innovations such as pelleting and priming.

Introduction

Seed is the fundamental input in agriculture and directly determines crop productivity. High-quality seed ensures uniform crop stands, better germination, and higher yields. However, seed quality is often threatened by factors such as moisture, temperature, storage pests, and seedborne pathogens. Even well-stored seed lots may deteriorate over time.

To overcome these challenges, seed treatment has become a cost-effective, preventive, and sustainable solution. By treating seed before sowing or storage, farmers can reduce crop losses, improve plant establishment, and minimize the use of pesticides in later crop stages. It acts as an insurance for crop success, ensuring that every seed sown has a better chance of survival and productivity.

Definition of Treated Seed

Treated seed is defined as seed that has been coated, soaked, or exposed to chemicals or biological agents designed to reduce, control, or repel insects, fungi, bacteria, nematodes, or other harmful organisms. Treated seed may also undergo processes such as hardening, pelleting, or priming to enhance vigor and stress tolerance. Such seeds not only show higher germination rates but also withstand adverse field conditions better than untreated seeds.

Types of Seed Treatment

1. Pre-sowing Seed Treatments
- Nutrient soaking: Paddy seeds soaked in 1% KCl for 12 hours.
- Micronutrient soaking: Pulses treated with $ZnSO_4$ or $MgSO_4$ solutions.
- Growth stimulants: Vitamins, hormones, and micronutrient solutions.

2. Insecticidal and Fungicidal Treatments

- Protection from soil-borne insects (wireworms, seed maggots).
- Reduced spread of fungal diseases (smuts, bunts).
- Higher germination rates.

3. Special Seed Treatments

- Seed hardening: Soaking and drying seeds to improve drought/cold tolerance.
- Fortification: Soaking seeds in nutrient solutions to supply essential elements.
- Pelleting: Coating small seeds with nutrients, adhesives, or inert materials for uniform sowing.
- Priming: Controlled hydration using osmotic agents (PEG, salts) to speed germination.
- Infusion: Introducing nutrients or hormones through organic solvents.

Fungicidal and Insecticidal Seed Treatments

Fungicidal Treatments: Classified into seed disinfection (kills internal pathogens), seed disinfestation (removes surface pathogens), and seed protection (safeguards from soil fungi). Non-volatile fungicides are most commonly used today.

Insecticidal Treatments: Protect seeds against storage insects and early soil pests. Combinations of chemicals are often used for broader protection, but compatibility and dosage are critical. These treatments give confidence to farmers that emerging seedlings will not be destroyed at early growth stages.

Pre-storage and Mid-storage Treatments

1. Pre-storage Treatments: Applied to freshly harvested seeds to prevent deterioration during storage.
- Halogenation
- Antioxidant treatments
- Seed sanitation

2. Mid-storage Treatments: Applied to seeds already in storage to restore vigor.
- Hydration–Dehydration: Soaking seeds briefly (2–6 hours) and drying back to safe moisture levels.
- Spraying or Moist Sand Conditioning: Controlled hydration to rejuvenate seed vigor.

These techniques reduce membrane damage, delay senescence, and maintain seed viability during prolonged storage. Farmers using these methods ensure long-term storage without significant loss in seed quality.

Safety Measures in Seed Treatment

Since most treatments involve pesticides, careful handling is necessary:

- Treated seeds must never be used as food or feed.
- Treatment should be carried out in well-ventilated areas.
- Protective clothing, gloves, and masks are essential.
- Containers should be clearly labeled and disposed of safely.
- Farmers should strictly follow recommended dosages to avoid toxicity.

Awareness campaigns are required so that farmers understand the health and safety risks linked to mishandling of treated seeds.

Conclusion

Seed treatment is a preventive, economical, and sustainable technique that plays a crucial role in securing crop productivity. By integrating chemical, biological, and advanced physical methods, farmers can achieve better germination, enhanced vigor, and improved resilience against pests and diseases. With proper safety measures and awareness, seed treatment can significantly reduce the need for chemical sprays later in the crop cycle, making agriculture more efficient and environmentally friendly.

Looking ahead, innovations such as bio-priming, nano-seed treatments, and microbial coatings promise to further revolutionize this field, helping farmers meet the global demand for food sustainably.

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The Biology and Innovative Nest Construction of Leafcutter Bees

Introduction

Among the vast diversity of bee species, one family stands out for its remarkable construction skills and specialized behavior is Megachilidae, commonly known as leafcutter bees. These extraordinary insects represent the second largest bee family after Apidae. Unlike their social honeybee, leafcutter bees lead solitary lives, each female independently mastering the art of precision leaf cutting and architectural nest construction. They are remarkable in their unique ability to cut and process fresh leaves for nest construction, a behavior exclusive to certain species within the genus *Megachile* Latreille (Rasmussen *et al* 2012). Using their specialized mandibles with razor-sharp interdental laminae, females execute perfectly smooth, half-moon cuts from leaf edges, creating distinct excision patterns that serve as their building materials (Michener 1964). This sophisticated behavior has evolved over millions of years, making leafcutter bees among nature's most skilled architects.

The Art of Leaf Cutting: Specialized Anatomy and Behavior

The secret to leafcutter bees' precision lies in their uniquely adapted mandibles. These powerful cutting tools feature interdental laminae, which are razor-like structures between the mandibular teeth that function like biological scissors. The opposing beveled edges of their mandibles work in perfect coordination, allowing females to cut circular to elliptical leaf pieces with remarkable accuracy (Gonzalez *et al* 2019). This morphological innovation represents a true evolutionary novelty among bees, as these specialized cutting structures are found nowhere else in the bee world. The presence and development of interdental laminae directly correlate with the extent of leaf-cutting behavior—species with complete laminae that entirely fill the spaces between teeth exhibit extensive cutting behavior, while those with incomplete or absent laminae show more limited leaf-cutting activities.

The cutting process itself is a marvel of precision engineering. Female bees select specific plants, particularly favoring species with glabrous leaves from families like Fabaceae and Rosaceae.

Fig. 1: **Nest made by leaf cutter bee**

They actively avoid latex-producing plants and show strong selectivity for leaves with appropriate phytochemical properties. Research has revealed that leafcutter bees can identify and collect leaves containing antimicrobial compounds such as flavonoids, phenols, and terpenoids, which provide protection against harmful microbes in their nests (MacIvor 2016).

Nest Architecture and Construction

Leafcutter bees are cavity-nesting specialists, utilizing a diverse array of pre-existing spaces for their architectural endeavors. In natural environments, they colonize hollow plant stems, abandoned beetle burrows in decaying wood, small cavities between stones, and niches in earthen banks. Remarkably adaptable, these bees also readily accept human-made structures, nesting in cracks in building walls, nail holes, and specially designed bee houses.

The nest construction process is a sequential masterpiece of engineering. Starting from the deepest point of the cavity, the female constructs a protective leafy wall using strips and circular discs of carefully selected leaves. Each nest cell requires 14-15 leaf pieces for complete construction, with the female meticulously chewing the edges of each piece to create a sticky pulp that binds the materials together. The architectural precision is remarkable where each cell measures approximately 11.16 mm in length and 6.22 mm in diameter for females, while male cells are slightly smaller at 9.29 mm in length and 5.45 mm in diameter. This size differentiation reflects the strategic resource allocation where female offspring, being larger and requiring more provisions, receive proportionally larger cells positioned toward the back of the nest for additional protection (Sabino and Antonini 2017).

A typical nest contains 5-12 cells arranged in a linear series, with each cell representing a complete life-support system for developing larvae. The entire construction process for a single cell requires approximately 81 minutes to 2.5 hours, during which the female makes 21 trips for construction and 18 trips for provisioning.

Life Cycle and Adult Behaviour

The leafcutter bee life cycle is a precisely timed sequence of development phases optimized for survival and reproduction. The cycle begins when males emerge 2-4 days before females in late spring or early summer, ensuring immediate mating opportunities when females become available. Mating occurs almost immediately after female emergence, after which males die and females commence their intensive nesting activities (Amala *et al* 2020).

Egg laying and provisioning represent a critical phase where females create provision masses weighing 90-94 mg, consisting of 33-36% pollen and 64-67% nectar by weight. These nutritionally dense provisions contain approximately 1.3 million pollen grains and are 47% sugar by weight. Interestingly, male offspring receive 17% fewer provisions than females, reflecting the smaller size requirements of males.

Larval development follows a rapid and efficient pattern. Embryogenesis takes 2-3 days, followed by five larval instars over approximately 20 days. The first instar remains within the egg chorion, while subsequent instars consume the provision mass with remarkable efficiency, where only 2% of provisions remain uneaten. The final fifth instar consumes the remaining provisions in just three days before defecating and spinning a tough, multilayered silk cocoon. The pupa initially appears pale yellowish white, and later gets pigmented towards the end of the pupation. Pupae will change shape, develop legs, a head, thorax, and abdomen. Next, the eyes will turn pink before darkening to black (female) or green (male) in *M. rotundata*. The body then begins to darken and the adult bee emerges out chewing away the transparent layer of the cocoon in the cell. Females live for about 5-8 weeks (Amala *et al* 2020).

Most species exhibit obligate diapause, overwintering as mature prepupal larvae in their protective cocoons. However, some populations display facultative bivoltinism, where up to half the early summer brood completes development to produce a second generation before late summer. Pupation occurs in early spring when temperatures reach 24-30°C, lasting 3-5 weeks before adult emergence.

Adults emerge in the opposite sequence to that in which they were laid in each nesting tube. The bee in the last cell formed in any tunnel is first to emerge.

The one immediately beneath it, or the second last egg to have been laid, yields the second bee, and so on to the bottom of the tube. There are some exceptions to this sequence, in which a bee will mature before the one immediately above it has emerged and in the process of emerging will chew through and destroy the other bee(s) and fortunately, it is a rare occurrence.

Mating occurs while females make their frequent rest stops and are basking in the sun. In habitats exposed to the sun, mating may occur immediately in front of the nest. However, if the nesting site is in the recess of a building, mating will usually occur in the sun near the point where females enter the building. A male lands on a female and lifts her abdomen with his legs. If the female accepts the invitation, she unites her genitals with those of the male. Mating lasts between 30 and 45 seconds. Females spend nights in their nest and are most active foraging on warm sunny days when temperatures exceed 20˚C. They generally do not forage when it is considerably cloudy or below 20˚C.

Conclusion and future prospectus

Leafcutter bees are outstanding examples of evolutionary adaptation and ecological specialization. Their distinctive behavior of cutting leaves, advanced nest-building techniques, and highly effective pollination make them essential contributors to both wild and farm ecosystems. In the context of worldwide declines in pollinator populations, it is increasingly important to study and protect these specialized builders to preserve ecosystem health and support agricultural yields.

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Global Warming and Livestock: A Climate-Resilient Path for India's Animal Agriculture

Introduction:

Global warming, a major outcome of human-induced climate change, has become a pressing challenge for global agriculture and livestock systems. Escalating temperatures, erratic rainfall patterns, more frequent droughts and floods, along with the rise of climate-sensitive diseases, are clear indicators of a warming planet. In India, where over 60% of the population depends on agriculture and allied sectors, the impacts are particularly profound. Among the hardest-hit sectors is livestock, which plays a pivotal role in rural livelihoods, food security, employment generation, and socio-economic stability.

India possesses the largest livestock population in the world and ranks as the top global milk producer. The sector is a significant contributor to the country's agricultural GDP and serves as a livelihood buffer for millions of small and marginal farmers. However, the growing intensity of climate change is disrupting this crucial sector—threatening animal health, productivity, fodder availability, and water resources (IPCC Sixth Assessment Report, 2022). In response, the focus on climate-resilient livestock systems is gaining momentum. There is a growing need to integrate adaptive strategies and sustainable practices that enhance resilience while minimizing emissions. This article delves into the interlinkages between global warming and livestock in India, and outlines strategies for building a climate-smart and sustainable animal agriculture system.

Image Source: FAO Website

What is Global Warming?

Global warming refers to the steady increase in Earth's average surface temperature, primarily driven by elevated levels of greenhouse gases like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). This rise is largely the result of human activities such as burning fossil fuels, industrialization, deforestation, and unsustainable agricultural practices, which have intensified the natural greenhouse effect. The Intergovernmental Panel on Climate Change (IPCC) reports that global temperatures have already increased by about 1.1°C since pre-industrial times and are projected to continue rising. The consequences of this warming are far-reaching and alarming—manifesting as more intense heatwaves, irregular rainfall, severe droughts and floods, melting glaciers, and rising sea levels. These shifts are not just environmental concerns; they directly and indirectly disrupt ecosystems, threaten biodiversity, affect water resources, reduce agricultural productivity, and endanger both human and animal health across the globe.

Indian Livestock Sector: An Overview

The livestock sector forms the backbone of India's rural economy, providing livelihood, nutrition, and socio-economic security to millions. According to the 20th Livestock Census (2019), India is home to over 535 million livestock, comprising cattle, buffaloes, goats, sheep, pigs, and poultry. The country is the world's largest milk producer and ranks among the top producers of meat, eggs, and wool.

Economically, the sector contributes approximately **5.5% to India's total Gross Value Added (GVA)** at current prices and more than 30% to the agricultural GDP (Department of Animal Husbandry and Dairying, Annual Report 2024–25). However, its importance goes beyond economics—livestock is deeply embedded in rural and tribal life, supporting traditional practices, food systems, and social structures. Women play a vital role, especially in managing small ruminants and dairy operations, making it a key sector for promoting gender equality.

Despite its significance, the livestock sector is increasingly vulnerable to climate change. Rising temperatures, erratic weather, and resource stress demand urgent adaptation and mitigation efforts to safeguard its sustainability.

Impacts of Global Warming on Livestock

Image Source: UN Website

1. Heat Stress and Animal Health

One of the most immediate and visible effects of global warming on livestock is increased heat stress. Animals, particularly cattle and buffaloes, are highly sensitive to changes in ambient temperature. When high temperatures are accompanied by humidity, it leads to thermal stress, significantly affecting animal health and performance.

Heat stress results in decreased feed intake, reduced growth rates, lower milk production, diminished fertility, and heightened susceptibility to infections and diseases. In dairy animals, milk yield can drop by 20–25% under extreme heat conditions (IPCC Sixth Assessment Report, 2022). Moreover, elevated temperatures interfere with metabolic functions, weaken the immune system, and disturb hormonal regulation, further compromising animal well-being. While indigenous breeds possess better heat tolerance compared to exotic ones, prolonged exposure to high temperatures can still adversely impact their health, productivity, and reproductive efficiency. Addressing heat stress is thus essential for sustaining livestock performance in a warming climate.

2. Reduced Fodder Availability

Climate change significantly hampers the growth and nutritional quality of fodder crops. Frequent droughts, shifting monsoon patterns, and irregular rainfall reduce the biomass yield of key forage species such as sorghum, maize, and Napier grass. The cultivation of water-intensive fodder varieties becomes increasingly difficult, particularly in arid and semi-arid regions already facing water scarcity. Moreover, elevated carbon dioxide levels and rising temperatures alter the composition of fodder, often increasing fibre content while reducing protein levels. This decline in nutritional value affects feed digestibility, ultimately impairing animal health, productivity, and reproductive performance. Ensuring consistent access to quality fodder under changing climatic conditions is thus a critical challenge for the livestock sector.

3. Water Scarcity

Water plays a vital role in livestock management—not only for drinking but also for cleaning, cooling, fodder production, and processing activities. However, climate change has intensified the depletion of water resources and increased the frequency of droughts, making the availability of clean and sufficient water for livestock a growing concern.

Several regions in India, including Marathwada (Maharashtra), Bundelkhand (Uttar Pradesh and Madhya Pradesh), and parts of Rajasthan, experience chronic water scarcity. Livestock in these areas, often dependent on natural water bodies and seasonal streams, are particularly vulnerable. The growing competition for water among agriculture, domestic use, and animal husbandry poses serious risks to livestock health, productivity, and survival.

4. Disease Incidence and Vector Spread

Global warming significantly affects the emergence, transmission, and spread of livestock diseases. Higher temperatures and increased humidity create favourable conditions for the multiplication of disease-carrying vectors like ticks, mosquitoes, and flies. These vectors are responsible for spreading infections such as Foot and Mouth Disease (FMD), bluetongue, hemorrhagic septicemia, and various tick-borne fevers.

Moreover, shifting climate patterns are altering ecological balances, enabling pathogens to survive and spread in new regions where they previously could not. This expansion of disease-prone zones increases the risk of outbreaks and presents serious challenges to animal health management systems, especially in regions with limited veterinary infrastructure. Strengthening disease surveillance and adaptive health services is essential to safeguard livestock in a changing climate.

5. Livelihood Insecurity and Socioeconomic Disruption

Climate-related declines in livestock productivity and rising mortality rates directly impact the livelihoods of farmers, particularly small and marginal holders. As livestock performance deteriorates, rural households experience a chain reaction—diminishing incomes, depletion of critical assets, worsening nutrition, and growing indebtedness.

The burden is especially severe for women and marginalized communities, who often depend on backyard poultry, small ruminants, and dairy animals as key sources of livelihood and food security. With increasing climate stress, coping strategies such as distress sale of animals, temporary migration, and abandonment of traditional grazing practices are becoming more frequent, further weakening rural resilience.

Livestock as a Contributor to Climate Change

Although livestock is heavily impacted by climate change, it also contributes significantly to the problem. Global livestock sector is responsible for approximately 14.5% of total greenhouse gas (GHG) emissions (FAO,2017). These emissions mainly originate from enteric fermentation in ruminants, which produces methane, and from manure management practices that release both methane and nitrous oxide. Additionally, emissions arise from the cultivation and processing of fodder, as well as from land-use changes—particularly deforestation to create grazing lands.

In the Indian context, the livestock sector's emission share is comparatively lower. This is largely due to the widespread presence of indigenous breeds, which are more efficient in low-input systems, and the relatively lower per capita consumption of meat. However, with growing demand for animal-based food products, emissions from the sector are expected to increase. This underscores the urgent need for adopting climate-smart livestock practices aimed at reducing the sector's environmental footprint while maintaining productivity.

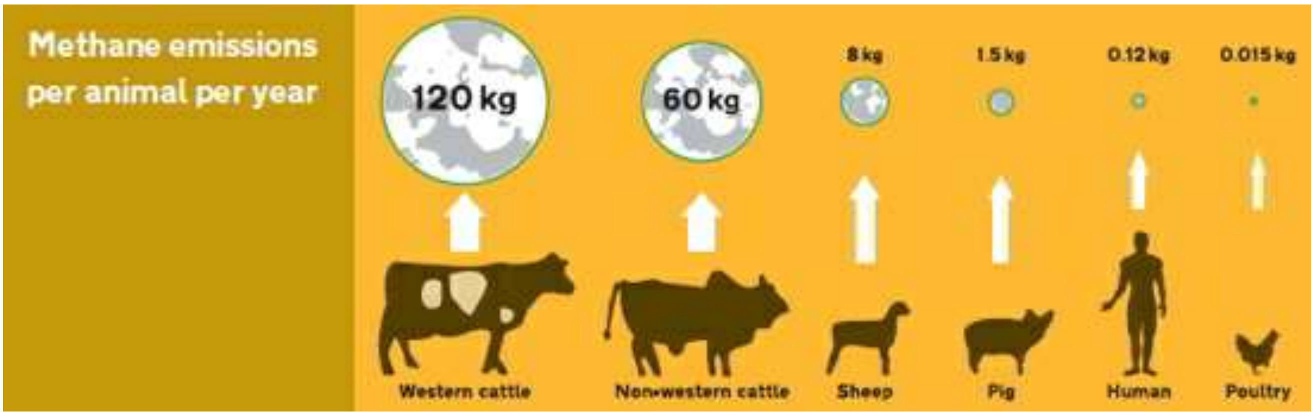
Towards Climate-Smart Livestock Production

The concept of Climate-Smart Livestock Production (CSLP) integrates adaptation, mitigation, and resilience-building strategies in livestock systems. It involves improving productivity and efficiency, reducing emissions, and enhancing the sector's capacity to cope with climatic shocks.

Image Source: FAO Website

1. Breed Improvement and Genetic Resource Conservation

Indigenous livestock breeds such as Gir, Sahiwal, and Tharparkar (cattle), Murrah (buffalo), and Malpura (sheep) possess inherent advantages in the face of climate change. These breeds are naturally more tolerant to heat, resistant to local



diseases, and well-adapted to low-input, resource-scarce environments. Promoting their use through selective breeding, scientific herd management, and conservation of native germplasm is a key strategy for enhancing resilience in livestock systems.

To strengthen these efforts, initiatives should also include community-driven breeding programs, the use of genomic selection tools, and strategic crossbreeding with climate-adapted traits. However, it is crucial to avoid the unregulated introduction of exotic high-yielding breeds, which may perform poorly under climate stress and require intensive inputs. Focusing on the genetic potential of native breeds offers a sustainable path for climate-smart animal agriculture.

2. Improved Feeding and Nutrition

To ensure consistent feed availability during periods of climatic stress, the adoption of nutritionally rich and drought-tolerant forage varieties—such as cowpea, bajra-napier hybrids, and legume-based pastures—is essential. These forages not only withstand water scarcity but also provide better nutritional support to livestock.

Additionally, utilizing crop residues, silage, mineral supplements, and compact feed blocks can significantly improve the nutritional intake of animals while also helping to reduce methane emissions. In regions facing acute water shortages, innovative solutions like hydroponic fodder production and azolla cultivation present viable alternatives. These technologies require minimal land and water and can be managed even by small and marginal farmers, contributing to climate-resilient livestock feeding practices.

3. Livestock Housing and Thermal Comfort

Enhancing livestock shelters with adequate ventilation, thermal insulation, and climate-control systems such as sprinklers, fans or foggers is essential to minimize heat stress in animals. Developing and promoting climate-resilient animal housing should be given priority within government programs like the National Livestock Mission (NLM), ensuring animals remain healthy and productive even under rising temperatures.

4. Animal Health Management

Developing climate-resilient animal health systems involves strengthening disease surveillance, conducting regular vaccination drives, and upgrading veterinary infrastructure. The integration of digital technologies—such as e-health cards, mobile advisory platforms, and GIS-based disease tracking—can enhance early warning capabilities and enable prompt response to emerging health threats, thereby reducing climate-related disease risks in livestock populations.

5. Government Schemes and Policy Interventions

The Government of India has launched several key initiatives to address the challenges posed by climate change in the livestock sector. The **National Livestock Mission (NLM)** emphasizes sustainable livestock development through improved fodder production, breed enhancement, and infrastructure support. The **Rashtriya Gokul Mission** focuses on conserving and promoting indigenous cattle breeds through scientific breeding programs. The broader **National Action Plan on Climate Change (NAPCC)** includes missions that address sustainable agriculture and promote strategic knowledge for climate adaptation. Additionally, the **National Adaptation Fund for Climate Change (NAFCC)** supports the implementation of climate-resilient livestock projects across vulnerable regions. The **Dairy Processing and Infrastructure Development Fund (DIDF)** aims to modernize dairy processing with climate-smart technologies and infrastructure.

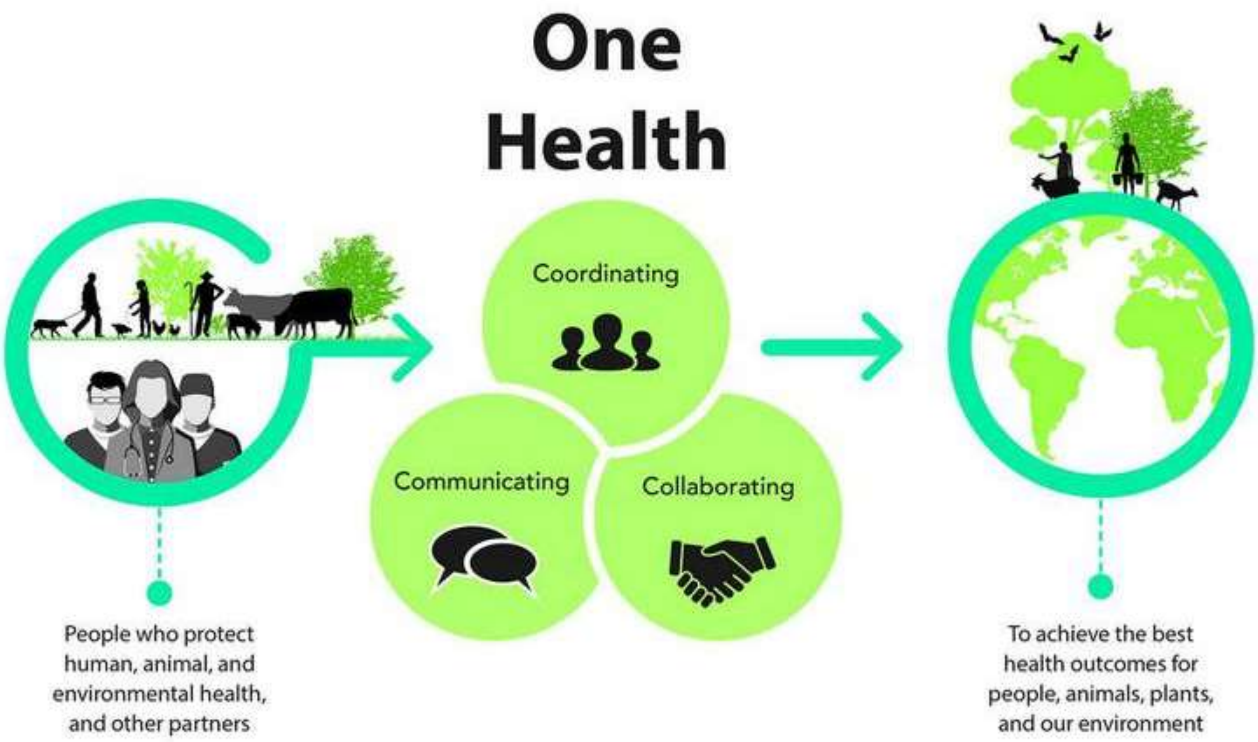
6. Role of Research and Innovation

Research and innovation are central to building climate-resilient livestock systems. Premier institutions like ICAR-NDRI, IVRI, and various state agricultural universities are leading efforts in this direction. Their work includes the development of heat-tolerant animal genotypes, climate-resilient fodder varieties, and livestock-based carbon budgeting models. They are also exploring methane inhibitors and designing tools for quantifying greenhouse gas emissions from livestock systems. In addition to public research, the private sector plays a vital complementary role. Innovations in climate-smart technologies, feed additives, livestock insurance products, and block chain-enabled traceability systems offer scalable solutions that enhance resilience, improve productivity, and reduce environmental footprints.

7. Community Participation and Extension Services

Image Source: One health Commission Website

Effective climate adaptation requires active involvement from farming communities. Raising awareness among livestock farmers about climate risks, adaptive practices, and available support mechanisms is essential. Participatory extension models, along with capacity-building workshops, climate field schools, and self-help groups, are powerful tools for enabling transformation at the grassroots level. Empowering women's groups and youth clubs through training in areas such as livestock first-aid, silage preparation, fodder bank management, and disaster preparedness can strengthen local resilience. Furthermore, community-based organizations should be entrusted with the management of local fodder resources, grazing lands, and primary veterinary services to ensure sustainable and inclusive



livestock development in the face of climate change.

Conclusion

Global warming poses a significant threat to India's livestock sector, affecting not just productivity but also rural livelihoods, nutrition, and gender equity. The challenge is multi-layer-spanning from animal health to water scarcity, feed shortages to disease outbreaks. However, this challenge also presents an opportunity to transition toward climate-smart animal agriculture that is efficient, sustainable, and resilient.

India's strength lies in its rich biodiversity, traditional knowledge systems, and grassroots institutions. By integrating scientific research, policy support, financial investment, and community participation, the country can build a livestock sector that withstands climate shocks while contributing to national development goals and global sustainability targets.

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Invasive Insect species in India

Non-native or Invasive or exotic or alien species are those species that reach out of their natural habitat beyond their dispersal ability. They produce huge negative impact on agriculture, biodiversity, human and animal health. International Union for Conservation of Nature and Natural Resources (IUCN) defines invasive alien species as those that becomes established in natural or seminatural ecosystems or habitat, and threatens the native biological diversity.

The exotic species are introduced to a new habitat either deliberately or unintentionally. They easily outsmart the native species, invade them and establishes in the new environment. Lack of natural enemies of these invasive species helps them to multiply enormously leading to loss of huge economic losses. Globalisation of agricultural trade had increased the risk of invasive pests.

The invasive alien species include various organisms like bacteria, fungi, algae, virus, fish, reptiles, birds or mammals. The invasive insect species belonged to orders along with their percentage namely, Hemiptera (63%), Lepidoptera (13%), Coleoptera (9%), Diptera (6%), Hymenoptera (6%) and Thysanoptera (3%). The invasive species show a significant impact on global economy with a cost of 1.28 trillion dollars for the last 50 years.

Attributes of Invasive alien species:

- Rapid growth
- High dispersal potential
- Generalist feeders
- Broad host range
- High egg laying capacity
- Compatible with new environment
- Highly Resilient
- Voracious
- Short life cycle
- Fast growth
- Competitive ability

Steps in invasion:

There are four stages of invasion by an alien species namely introduction, establishment, spread and naturalization.

a. **Introduction:** Invasive species are introduced mainly through long distance migrations or through transportation. Many of them were unintentionally transferred through shipping containers, tourists, airplanes, etc., while some are brought intentionally for management purpose of native species. But these species become pests instead of managing the native pest.

b. **Establishment:** An insect is considered as invasive only when it overcomes the native species and establishes in the new environment. Establishment of an alien species depends on its population size. Increased availability of resources and decreased biotic resistance allow an insect to establish in a new habitat.

c. **Spread:** The invasive species moves from initial place of establishment to another place. Its spread depends on weather conditions, predators, resource availability, population size and microclimate. The spread also occurs due to behavioral or morphological changes. It has to overcome biotic and abiotic barriers to spread into a new habitat.

d. **Naturalization:** It is the final step of invasion. The exotic species after overcoming the biotic and abiotic barriers to its survival rate, its reproduction is regularised. The species become part of the habitat threatening the native biodiversity.

List of invasive insect pests in India:

S.I N O.	NAME	ORIGIN	YEAR	HOSTS
1	San Jose scale *Quadraspidiotus perniciosus*	China	1879	Rosaceous fruit plants
2	Woolly aphid *Eriosoma lanigerum*	China	1889	Apple, Pear
3	Diamondback moth *Plutella xylostella*	Italy	1914	Cruciferous vegetables
4	Lantana bug *Teleonemia scrupulosa*	Sri Lanka/West Indies	1915	Lantana, coffee, Citrus, potato, brinjal, rose
5	Cottony cushion scale *Icerya purchase*	Australia	1921	wide range of forest trees
6	Potato tuber moth *Phthorimaea operculella*	Italy	1937	Potato, tomato, Tobacco, brinjal, and stored potato
7	Sugarcane woolly aphid *Ceratovacuna lanigera*	Indonesia	1958	Sugarcane
8	Pine woolly aphid *Pineus pini*	Western and Central Europe	1970	*Pinus patula*
9	Subabul psyllid *Heteropsylla Cubana*	Central America	1988	*Leucaena* sp.
10	Coffee berry borer *Hypothenemus hampi*	Northeast Africa	1990	coffee
11	Serpentine leaf miner *Liriomyza trifolii*	USA	1990	Polyphagous
12	Spiralling whitefly *Aleurodicus disperses*	Central America	1993	Polyphagous
13	Silver leaf whitefly *Bemisia argentifolii*	USA	1999	Tomato, Egg plant, Okra, and Cotton
14	Litchi longhorn beetle/ Guava stem borer *Aristobia reticulator*	China	2000	Litchi, Guava
15	Blue gum chalcid *Leptocybe invasa*	Australia	2001	Eucalyptus

16	Cotton mealybug *Phenacoccus solenopsis*	USA	2005	Black pepper
17	Lotus lily midge *Stenochironomus nelumbus*	China	2005	Lotus
18	Erythrina gall wasp *Quadrastichus erythrinae*	Tanzania, East Africa	2006	Cotton, okra, brinjal, tomato, sunflower, sesame, rose
19	Papaya mealybug *Paracoccus marginatus*	Central America	2007	fruits, flowers and plantation crops
20	Jack Beardsley mealybug *Pseudococcus jackbeardsleyi*	America	2012	Banana
21	Madeira mealybug *Phenacoccus madeirensis*	Neotropical	2012	Hibiscus
22	South American tomato leaf miner *Tuta absoluta*	South America	2014	Tomato, potato, brinjal, pepper
23	Invasive thrips *Thrips parvispinus*	Indonesia	2015	Chilli
24	Western flower thrips *Frankliniella occidentalis*	America	2015	Polyphagous
25	Coconut Spindle infesting leaf beetle *Wallacea* sp.	Australia	2015	Coconut

26	Rugose spiralling whitefly *Aleurodicus rugioperculatus*	Central America	2016	Coconut, banana, guava, mango
27	Fall armyworm *Spodoptera frugiperda*	Africa	2018	Polyphagous pest
28	Bondar's Nesting Whitefly *Paraleyrodes bondari*	Central America	2018	Coconut
29	Nesting whitefly *Paraleyrodes minei*	Syria	2018	Coconut
30	Brow peach aphid *Pterochloroides persicae*	Middle East	2018	Peach and citrus
31	Woolly whitefly *Aleurothrixus floccosus*	Neotropical region	2019	Citrus, Guava
32	Neotropical whitefly *Aleurotrachelus atratus*	Neotropical region	2019	Coconut
33	Cassava mealybug *Phenacoccus manihoti*	Africa	2020	Cassava
34	Bagrada bug *Bagrada hilaris*	Africa	2023	Brassica
35	Apple leaf blotch miner *Leucoptera malifoliella*	Europe	2023	Apple, peach, pear
36	Mango soft scale *Fistulococcus pokfulamensis*	Hong kong	2023	Mango and jamun
37	Annona whitefly *Aleurotrachelus anonae*	China	2024	Custard apple and Indian shot

Impact of invasive pest species on Indian agriculture:

- The invasive alien species pose a serious threat to biodiversity and ecosystems
- With the lack of natural enemies, they outcompete native species for resources leading to disturbances in ecological balance
- They can alter the structure, species composition, nutrient cycles and productivity of an ecosystem
- They can disrupt the biodiversity by eliminating several species of an ecosystem
- They become predators or pests on native insect or plant species
- They also act as vectors of several diseases that seriously impacts health of native species
- They cause crop losses that can lead to huge economic losses thereby affecting GDP of a country

Plant quarantine:

Plant quarantine is a legal method of pest management. It restricts the movement of an exotic organism into a new region by imposing legal actions on transport of agriculture commodities, seeds, grains and planting materials without prior inspection.

It is regulated by Directorate of plant protection, quarantine and storage with its headquarters located at Faridabad, Haryana. The DPPQS works through Plant Quarantine Order (2003) formerly Destructive Insect and Pest Act, 1914 at 71 quarantine stations throughout India. It provides a legal certificate called 'Phytosanitary certificate' which means the agriculture commodity is clean and free of any exotic or new organisms to the region of entry.

Conclusion:

Early detection of an invasive species is crucial for designing management strategies. But taxonomic identification at species level is a constraint. Strict quarantine and pesticide application measures are most effective in controlling an invasive species. It is because the quarantine restricts the further movement and pesticides provide instant mortality. But with availability of natural enemies, these invasive species can be controlled which is long lasting and cost effective.

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Cordia dichotoma (Lasuda) - A Practical Guide for Cultivation and Management

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Scientific name: *Cordia dichotoma* Forst.
Common name: Lasuda, Solora, Indian cherry
Family: Boraginaceae
Chromosome Number: 2n= 48

Introduction

Cordia dichotoma Forst. is a species of flowering tree in the borage family, Boraginaceae, which is native to the China and northern Australia. It is an important multipurpose fruit tree species distributed in arid and semi-arid regions of India. Its versatile adaptability to poor soils, wastelands and tolerance capacity to water stress makes it suitable plant for arid ecosystem. The species is known for its nutritious fruits and diverse uses of other plant parts. It is generally planted as shelter belt on farm boundaries, but now days; it is grown as planned orchard to fetch premium prices from its fruits in summer season.

Cordia dichotoma is small to medium-size deciduous tree with a short, crooked trunk, short bole and spreading crown. The plant is medium growing tree attaining a height of 10.5m. The polygamy of the plant is indicative of its popularity across many geophysical environments.

Climate and soil

C. dichotoma is commonly cultivated in tropical and subtropical regions of the country. It can also be grown in the sub-Himalayan tract ascending up to about 1 500 m elevation. It is found in divers of forests ranging from the dry deciduous forests of Rajasthan to the moist deciduous forests of Western Ghats in India and tidal forests in Myanmar. It is sporadically cultivated in Ludhiana, Amritsar, Bathinda, Ferozpur and Patiala. It can tolerate temperature as high as 49°C. Rainfall to the extent of 250-300 mm is sufficient to meet out the requirement. Lasuda is not very strict in soil requirement and can be grown successfully in wide range of soil. However, it grows well on sandy to clay loam soil and is tolerant to salinity.

Propagation

Lasuda can be propagated by seeds as well as by vegetative means. The seeds extracted from freshly harvested ripe fruits are sown in polybags during June-July. Among the vegetative methods, "T" budding has been found successful with more than 90% success was obtained during August month.

For budding it is recommended that 60-75 days old seedling rootstocks need to be used as a rootstock.

Planting

Under arid conditions, the best planting time is during July-August. Systematic planting can be done at a spacing of 5-7m depending upon the rain fall and soil types. Pits of the size of 60 x 60 x 60 cm are dug out during May- June to ensure natural sterilization of soil through intense solar radiation.

Varieties

A. **Maru Samridhi:** This variety has been released by Central Arid Zone Research Institute, Jodhpur recently. It is an improved high yielding variety with an averages fruit yield of 85 kg fruits/plant. Mean plant height and canopy diameter is 4.5 m and 7 m respectively. Its flowering occurs during February-March and fruits mature during April-May. It is the most suitable for cultivation in Punjab due to its adaptability to the climatic and soil conditions of the region.

B. **Thar Bold:** A prolific and early bearing lasuda (*Cordia dichotoma*) has been identified as "Thar Bold" (CIAH/ LS-3) through selection. It bears bold fruits in cluster with high production of 1.5-2.0 quintal tender fruits per tree per year. This variety is recommended for commercial cultivation both as block plantation and also a component of agro-forestry system in arid and semi-arid region of the country.

C. **Karan Lasuda:** Variety released by Sri Karan Narendra Agriculture University (SKN), Jobner centre with the name 'Karan Lasoda'. The buded plants grow fast and attain good growth (5.45m) and yield fruits in 4-5 years.

Irrigation

Regular irrigation is required during initial three years. In general, irrigation at 15 days during winter and at 7-10 days interval during summer is sufficient for newly planted plants. Irrigation should be provided during active growth period. Light irrigation should be done at weekly interval during flowering to maintain turgidity to prevent fruit drop. Manuring and irrigation are started from first week of February onwards with the rise in temperature. This ensures new growth and flowering which occur almost simultaneously. Regular irrigation is given after this till April or when fruit harvest is completed.

Manure and Fertilizers

The amount of fertilizer largely depends upon the age and size of tree. The nutrient requirement of the plant has not been standardized. However, application of well rotten farmyard manure: 20 kg per plant during July-August and 20 kg per plant during February before flowering is sufficient for optimal fruiting.

Disease and Insect

Gummosis induced drying of branches that occur invariably on *lasuda* plants during March-April, September-October. The gum flow in the phloem region of branches which causes the terminal branches to dry. There is no serious pest on *lasuda* except that sometimes aphids/jassids infect the young leaves and inflorescence during cloudy days which normally do not affect much to the plants as they disappear during sunny days. In case the infection persists, it can be controlled easily with the spray of monocrotophos 25% SL @1 ml/liter water.

Harvesting and Yield

Flowering starts in last week of February and fruit set in the month of March-April. The fruits are ready for harvest after about 30-45 days of fruit set. The fruits are harvested at mature green stage before initiation of ripening for culinary purposes. The harvesting has to be done in staggered manner as all fruits do not mature at the same time and should be completed by first week of May. Fruits start ripening during first week of May. Fruits turn yellowish cream upon ripening and are very sweet.

Benefits of *Cordia dichotoma* Forst.

A. Medicinal importance: The kernels of the fruit are a good remedy for ringworms. The decoction of leaves is used in cough and cold. The decoction of bark is found useful in calculous infection, dyspepsia and fever. Moistened bark is applied externally on boils, tumours and powder is used to cure mouth ulcers. The mucilage in the fruits is used to treat the disease of uterus, chest and urethra.

B. Ethnobotanical Uses: The raw fruits are preserved in the form of pickles and also cooked as vegetable. The ripe fruits are edible, sweet and cooling. Tender leaves are also cooked as green leafy vegetables. Leaf ash mixed with honey is recommended for constipation.

C. Classical Uses: It is a very good shade tree. Lasuda contain allantoin, a kind of herbal medicine that hastens the healing process.

D. Nutritional Profile: The whole plant of *C. dichotoma* is edible and is used as food. Immature fruits are pickled and are also used as vegetable. Mixture of flower and curd applied two times in a day used to protect body against heavy sun heat waves. The rural people of coastal areas of Orissa eat the ripe fruits raw. The seed kernels of *C. dichotoma* contain high quantity of fatty oils and proteins which has potential as cattle feed. The polysaccharide gum (97%) obtained from the plant used for various pharmaceutical purposes. Chromium present in the fruit has therapeutic value in diabetes. A fruit also contains some anti-nutritional factors such as phytic acid (355 mg), phytate phosphorus (100 mg) and oxalic acid (250 mg) per 100 g. New natural cellulose fabrics were identified from the branches of the *C. dichotoma*.

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Rice and Wheat Monoculture in Punjab: Challenges and Solutions

Abstract

Punjab has played an important role in feeding India after the Green Revolution. Farmers in the state mainly grow rice and wheat, which gave good yields in the beginning. But growing the same crops again and again has now created serious problems for soil, water, farmers' economy, and the environment. This article explains how the rice–wheat system is harming sustainable farming and also suggests practical solutions like crop diversification, better water use, and residue management.

Introduction

Punjab is called the "Granary of India" because of its large contribution of food grains. The rice–wheat system became popular during the Green Revolution due to government policies, irrigation facilities, and assured procurement. For many years it ensured food security for India, but today it has become unsustainable. This system is damaging soil health, water resources, biodiversity, and air quality, while also creating economic and health issues for farmers.

Historical Background of Rice-Wheat Monoculture

Before the Green Revolution, Punjab farmers mainly grew maize, pulses, and oilseeds along with wheat. Rice was not a traditional crop of Punjab because it requires huge amounts of water. However, during the 1960s and 1970s, government policies encouraged farmers to grow rice along with wheat due to the demand for food grains. Assured prices (MSP) and easy procurement by the Food Corporation of India made rice a profitable choice. This policy created the rice–wheat rotation system that dominates Punjab today.

Nutrient Imbalance in Soil

Continuous cultivation of rice and wheat has removed the same type of nutrients from soil every year. Farmers have tried to replace nutrients by adding chemical fertilizers, especially nitrogen, but this has created imbalance. Soils in Punjab are now deficient in micronutrients like zinc, iron, and sulfur. This reduces crop productivity and increases dependence on external inputs.

Salinity and Alkalinity of Soil

Due to over-irrigation, waterlogging, and poor drainage in some areas, soils are becoming saline and alkaline. High salt content in soil affects plant growth and lowers yields.

Soil structure is also damaged when excess irrigation brings salts to the surface, making the land less productive.

Underground Water Depletion and Pollution

Rice cultivation in Punjab requires nearly 4000–5000 liters of water per kilogram of grain. Farmers pump groundwater to meet this demand, which has led to a rapid fall in water levels. More than 100 blocks in Punjab are categorized as over-exploited. Along with depletion, groundwater is also polluted by seepage of fertilizers and pesticides. Chemicals such as nitrates contaminate water used for drinking, causing health hazards.

Impact on Soil Microorganisms

Healthy soils depend on microorganisms like bacteria, fungi, and earthworms that recycle nutrients. Overuse of fertilizers and pesticides harms these organisms, reducing soil fertility. Burning rice straw also kills microbes on the soil surface. Loss of beneficial microbes disturbs soil ecology and increases dependence on chemical inputs.

Air Pollution from Stubble Burning

After harvesting rice, farmers burn the leftover straw to quickly prepare fields for wheat. This burning produces smoke, particulate matter, and gases like carbon dioxide and carbon monoxide. Stubble burning not only pollutes air and harms health but also reduces organic matter in soil, worsening soil quality.

Loss of Biodiversity

Because of the rice–wheat focus, other crops such as maize, pulses, and oilseeds have disappeared from Punjab. This loss of diversity makes farming more vulnerable to pests, diseases, and climate change. Crop diversity is important for soil fertility and long-term sustainability.

Pesticide Overuse and Consequences

Rice cultivation needs frequent pesticide sprays, and their overuse has created new problems. Pests develop resistance, forcing farmers to use stronger chemicals. Residues from pesticides pollute soil, water, and food, and also harm non-target species including pollinators and natural predators.

Impact on Human Health

High use of fertilizers and pesticides has contaminated water and food in Punjab. This has been linked to rising cases of cancer, especially in districts like Bathinda and Mansa, known as the 'cancer belt'. Air pollution from stubble burning also increases respiratory diseases and asthma cases, affecting not only Punjab but neighboring states as well.

Effect on Climate Change

Paddy fields release methane, a powerful greenhouse gas that contributes to climate change. Stubble burning adds carbon dioxide and other gases into the atmosphere. Thus, rice–wheat monoculture indirectly increases the problem of global warming.

Economic Challenges for Farmers

Though MSP assures income for rice and wheat, the rising cost of fertilizers, diesel, and electricity has reduced profits. Farmers are trapped in debt cycles because of increasing input costs and stagnant income. Small farmers are particularly affected and are unable to invest in sustainable practices.

Government Efforts and Policies

The Punjab government and central schemes have tried to promote crop diversification and residue management. Subsidies for Happy Seeder and Rotavators are provided to reduce stubble burning. Programs like 'Mera Pani Meri Virasat' aim to reduce rice cultivation. However, farmers are reluctant to shift because alternative crops do not have assured procurement like rice and wheat.

Solutions to Overcome the Problem

1. Promote Crop Diversification: Encourage farmers to grow maize, pulses, oilseeds, vegetables, and fruits with assured marketing support.

2. Save Water in Farming: Adopt Direct Seeded Rice (DSR), System of Rice Intensification (SRI), drip and sprinkler irrigation, and recharge structures.

3. Improve Soil Health: Use organic manure, compost, biofertilizers, and green manuring to restore fertility.

4. Manage Crop Residues: Provide machinery like Happy Seeder and promote composting and bio-energy plants.

5. Policy Support: Expand MSP to alternative crops, provide crop insurance, and strengthen extension services for awareness.

Future Prospects

Punjab must move toward sustainable agriculture models that combine modern technology with traditional knowledge. Precision farming, organic farming, and integrated pest management can help. If crop diversification is properly supported, Punjab can become a model for environmentally friendly and profitable farming.

Conclusion

The rice–wheat system helped India overcome food shortages in the past but has now become a threat to sustainability. It has created soil problems, groundwater crisis, biodiversity loss, health hazards, and economic stress. To secure the future of farming, Punjab must adopt sustainable practices with government support. Crop diversification, water-saving methods, and eco-friendly residue management are essential for long-term prosperity.

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SRBSDV: An Emerging Concern for Rice Farmers in Northern India

Introduction:

India is the world's top exporter and second-largest producer of rice. India's main basmati-producing region is the Indo-Gangetic plains in North India, which is renowned for its rice cultivation. Rice production is affected by various diseases caused by wide range of pathogens. This year rice cultivation is facing threat from the Southern Rice Black-Streaked Dwarf Virus (SRBSDV). During the *Kharif* season of 2022, this virus was first reported in rice fields of Uttarakhand, Haryana and Punjab in India. Both basmati and non-basmati varieties growing areas had considerable incidence of disease. The disease incidence ranged from 1–10% in the affected fields and up to 20% in severely affected fields at Kutani and Panipat. Early in *Kharif* 2025, symptoms of virus are coming again from different parts of Punjab and Haryana.

Fig: 1 Symptoms of southern rice black-streaked dwarf disease. (A) Very early infected seedlings (right) showing dwarfism and stiff leaves. **(B)** Diseased plant (front) infected at the seedling stage showing severe stunting and withering after transplanting. **(C)** Diseased plant (front) infected at the early tillering stage showing dwarfism and excessive tillering. **(D)** Diseased head showing small spikes and barren grains. **(E)** Aerial rootlets and branches on the stem nodes of an infected plant. **(F)** Small streaked white or black waxy galls on the stems of an infected plant. **(G)** Poorly developed brown roots (right) of an infected plant.

First identified in 2008, the Southern Rice Black-streaked Dwarf Virus (SRBSDV) is a novel species of *Fijivirus* (family *Reoviridae*) that is non-enveloped and icosahedral, having a genome consisting of 10 double-stranded RNA segments. The virus can be efficiently transmitted by the white-backed planthopper (WBPH, *Sogatella furcifera* Hemiptera: Delphacidae) in a persistent circulative propagative manner. WBPH can infect grass weeds, rice, maize, and barnyard grass. However, due to the vector's preference, only rice contributes significantly to the virus infection cycle. White-backed planthoppers have better transmission efficiency as compared to little brown planthoppers. The younger the rice seedling is, higher the transmission efficiency. According to epidemiological studies, it spreads through long-distance migration of WBPH, a highly effective vector of SRBSDV. The overwintering of SRBSDV happens either through viruliferous WBPH vectors or through alternate hosts like rice, maize and other grassy weeds. Since SRBSDV infection is not found in the immature seeds of affected plants hence it is not seed transmitted. However, it's a matter of debate how the viruliferous WBPH spreads to the affected rice belt in Northern India and establish the primary inoculum. To address this emerging disease in rice, a thorough study of the overwintering virus and alternative and vector hosts is required.

Symptoms of SRBSDV on rice plants:

Although rice is susceptible to SRBSDV at every growth stage, the symptoms and yield losses vary depending on the growth stage at the time of infection. Earlier infection leads to severe symptoms. Plants infected at the early seedling stage exhibit dwarfism and stiff leaves. Severe diseased plants may wither and die as there is severe stunting and failure of elongation. Stunting was observed either in the form of individual plants scattered at different parts of a field or as group of 4–10 dwarf plants occurring in the patches. Significant dwarfing, excessive tillering and failure to head emergence are the effects of infection at the early tillering stage. Although the plants are not stunted by infection during the elongation stage, but have tiny spikes, barren grains and low grain weight. The diseased leaves are rigid, short, dark green and ruffles often appear on the surface of the upper leaves and near the leaf base. Plants infected at the booting stage show no visible symptoms but the infection can be verified using the reverse-transcription polymerase chain reaction (RT-PCR) or enzyme-linked immunosorbent assay (ELISA). The disease's most typical symptoms such as dark green foliage, aerial rootlets, branches on the stem nodes, tiny streaked, black or white, waxy galls 1-2 mm in size on the stems and poorly developed brown roots are typically seen in plants infected prior to the tillering stage after elongation. The length of the roots decreases and they become fibrous. Pulling off the diseased tillers is easy. The late-planted crop (sown after the second week of July) has a lower disease incidence as compared to the early-sown crop (planted in the second fortnight of June).

Disease spread:

The virus is transmitted by the insect, white-backed planthopper (WBPH-*Sogatella furcifera*). The adults and nymphs of WBPH spread the disease. The insects inhabit at the base of the plant, above the water level. The insect is more likely to attack in overcast, humid weather. The virus spreads as a result of WBPH migrating from one plant to another and from one field to another.

Management of disease:

- WBPH nymphs and adults cause spread of the virus. Therefore, WBPH control in the field is the primary factor in disease management.

- Growing resistant/tolerant cultivars in the affected regions.
- Light traps are installed to monitor adult WBPH activity.
- Maintain a weed-free nursery, field and surroundings
- Roguing of affected plants from the field helps prevent the disease from spreading further.
- In the nursery stage, when seedlings are 15 to 20 days old, a preventative insecticide application can kill the insect.

The recommended insecticide for controlling white-backed planthoppers

S. No.	**Insecticide name**	**Dosage**
1	Benzpyrimoxan 10% SC	1.5 ml/litre
2	Dinotefuran 70 % WG	0.2 gm/l
3	Ethofenoprox 10 % EC	1 ml/l
4	Fipronil 05 % SC	2 ml/l
5	Fipronil 00.30 % GR	16- 25 kg/ha
6	Imidacloprid 70 % WG	0.1 gm/l
7	Imidacloprid 17.80 % SL	0.2 ml/l
8	Thiamethoxam 25 % WG	0.2 gm/l
9	Fipronil 04 % + Thiamethoxam 04 % w/w SC	2.2 ml/l
10	Thiocyclam Hydrogen Oxalate 3.0% + Clothianidin 1.2% GR	10-12.5 kg per ha

(Source: *CIBRC recommendation dated 31.03.2025*)

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Fall Armyworm (*Spodoptera frugiperda*): A Global Agricultural Challenge and Integrated Management Solutions

Abstract

The Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) is one of the most destructive invasive pests threatening agriculture worldwide. Since its introduction into Africa in 2016 and Asia in 2018, it has rapidly spread, affecting more than 80 host plant species. This pest's polyphagy, high migratory ability, prolific reproduction, and ability to develop resistance against multiple insecticides and Bt crops make it especially challenging to manage. This review consolidates global research on FAW biology, ecology, and economic impact, with particular emphasis on integrated pest management (IPM). Recent advances in genomics, molecular biology, resistance monitoring, and digital tools such as mobile-based pest monitoring systems are also discussed. Finally, future prospects highlight the importance of international collaboration, policy frameworks, and farmer-centric innovations to mitigate FAW's threat sustainably.

Introduction

Biology and Identification

The **Fall Armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith)**, is a polyphagous, highly migratory lepidopteran pest native to the tropical and subtropical Americas. Over the last decade, it has emerged as a **global agricultural threat**, invading Africa in 2016, Asia in 2018, and more recently Oceania (FAO, 2018; CIMMYT, 2019). Its rapid transcontinental spread is facilitated by its strong flight capability, adaptability to diverse agro-ecologies, and wide host range of more than **350 plant species**, including maize, rice, sorghum, sugarcane, cotton, and several vegetable crops (Day et al., 2017; ICAR, 2020).

Agricultural and Socio-Economic Relevance

Maize, the primary host of FAW, is the **staple food for over 300 million people in sub-Saharan Africa** and a critical livelihood source for millions of smallholder farmers across Asia and Latin America (FAO, 2019). FAW infestations can lead to yield losses ranging from **8–21 million tonnes of maize annually in Africa alone**, translating into economic losses of USD **2.5–6.2 billion** (FAO, 2018).

In India, surveys by ICAR reported infestation levels of 50–80% in maize fields within two years of the pest's arrival (Sharanabasappa et al., 2018). The socio-economic burden is particularly severe for **smallholder farmers**, who have limited access to timely pest control technologies and depend on maize and sorghum for both food and income. In regions like Kenya, Ethiopia, and India, farmers have resorted to frequent chemical spraying, which increases production costs, raises health and environmental risks, and accelerates pesticide resistance (CABI, 2019).

Invasion Biology and Global Risks

FAW's invasive success is linked to:

- **High reproductive capacity**: Females can lay up to 2,000 eggs.
- **Long-distance migration**: Adults can fly 100 km per night, with seasonal wind-assisted dispersal allowing continental spread (Early et al., 2018).
- **Polyphagy**: Ability to feed on a broad spectrum of crops.
- **Genetic plasticity**: Presence of **corn (C) and rice (R) strains**, with potential hybridization, increases adaptability (Nagoshi et al., 2017).

These features make FAW not just an agricultural problem but a **biosecurity challenge** requiring transboundary collaboration.

Climate Change Dimensions

Climate change is expected to **exacerbate FAW outbreaks** by altering pest phenology, distribution, and migration patterns. Rising temperatures shorten FAW's developmental cycle, potentially increasing the number of generations per year (Maino et al., 2021). Modeling studies predict a **northward expansion of FAW into southern Europe and temperate Asia**, threatening new agroecosystems (Du Plessis et al., 2018). Shifts in rainfall and extreme weather events may also stress crops, making them more vulnerable to FAW damage.

Furthermore, pest management strategies may become less effective:

- Heat stress can reduce the efficacy of biological control agents (e.g., parasitoids).
- Prolonged dry spells may encourage FAW survival on alternative hosts.
- Increased insecticide use in response to climate-driven outbreaks raises risks of resistance and ecological disruption.

Table 1. Estimated maize yield losses due to FAW in different regions.

Region	Estimated Loss (%)	Economic Loss (USD)	Source
Sub-Saharan Africa	8–21 million tonnes	2.5–6.2 billion	FAO (2018)
India (2018–19)	50–80% fields infested	–	ICAR (2020)
Brazil (Bt maize)	Up to 34% under resistance cases	>1 billion annually	Farias et al. (2014)

Reference : FAO & PPD. *Manual on Integrated FAW Management* (2020) (Open Knowledge FAO)

Rationale for Review

Given its **economic importance, ecological adaptability, and policy relevance**, FAW has attracted intense research worldwide. However, gaps remain in understanding strain dynamics, resistance mechanisms, socio-economic trade-offs, and sustainable management pathways. This review synthesizes global knowledge on FAW's biology, invasion ecology, and management strategies, while highlighting research gaps and the implications of **climate change** and **socio-economic vulnerabilities**.

The Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) is a polyphagous lepidopteran pest belonging to the family **Noctuidae**. It is native to the tropical and subtropical regions of the Americas but has now spread globally. Correct identification is critical, since FAW larvae resemble other armyworm species.

Morphology

- **Eggs:** Laid in clusters of 100–200, covered with a protective layer of scales. Eggs are dome-shaped, cream to light green in color, turning darker before hatching.
- **Larvae:** The most damaging stage, consisting of six instars. Characteristic features include:
    - An **inverted Y-shaped marking** on the head capsule.
    - Four distinct dark spots arranged in a square on the dorsal side of the 8th abdominal segment.
- **Pupa:** Brown, smooth, cylindrical, found in soil.
- **Adult moth:** Grayish-brown forewings with irregular patterns, hindwings white with dark margins. Males show more mottled wing patterns compared to females.

Life Cycle

FAW completes its life cycle in **30–40 days under tropical conditions**, though duration varies with temperature.

- Egg stage: 2–3 days
- Larval stage: 14–22 days
- Pupal stage: 7–13 days
- Adult lifespan: 7–21 days

Each female can lay **1,000–2,000 eggs** in her lifetime, contributing to rapid population outbreaks.

Feeding Behavior

FAW is a **voracious feeder** with chewing mouthparts. Young larvae feed on leaf surfaces, while older larvae move into the whorl, ear, or reproductive parts of plants. Feeding damage includes skeletonization of leaves, presence of frass (excreta), and boreholes in stems or cobs.

Strains and Molecular Characterization

A key biological feature of FAW is the existence of **two strains**, first described in the Americas and later confirmed in invasive populations:

1. **Corn strain (C-strain):**
    - Prefers maize, sorghum, and cotton.
    - Associated with more severe outbreaks on cereals.
    - More commonly found in Africa and Asia during FAW invasions.
2. **Rice strain (R-strain):**

- Prefers rice, pasture grasses, and turf grass.
- Plays a greater role in damage to rice ecosystems and forage crops.

Differences:

- **Morphological:** Virtually indistinguishable in appearance.
- **Molecular:** Differentiated using mitochondrial COI (cytochrome oxidase I) and nuclear Tpi (triose phosphate isomerase) gene markers.
- **Behavioral:** Variation in host preference and oviposition behavior.
- **Resistance traits:** Some studies indicate strain differences in insecticide resistance levels and Bt tolerance (Juárez et al., 2012; Zhang et al., 2019).

Hybridization:

The two strains often hybridize, especially in invasive regions, leading to **genetic introgression**. Hybrid populations may combine traits of both strains, complicating host preference predictions and resistance management (Nagoshi et al., 2017).

Reference CIMMYT. FAW-tolerant maize hybrids for Africa (2020) (CIMMYT)

Strains and Molecular Characterization

FAW has two strains – the **corn strain** and the **rice strain** – which differ in host preference, genetic makeup, and insecticide resistance. Molecular markers (mitochondrial COI, nuclear Tpi) have been used to track these strains across continents (Zhang et al., 2019). Hybridization between strains complicates management since hybrids may carry adaptive traits enhancing survival in new environments.

Distribution

Native Region & Spread to Africa

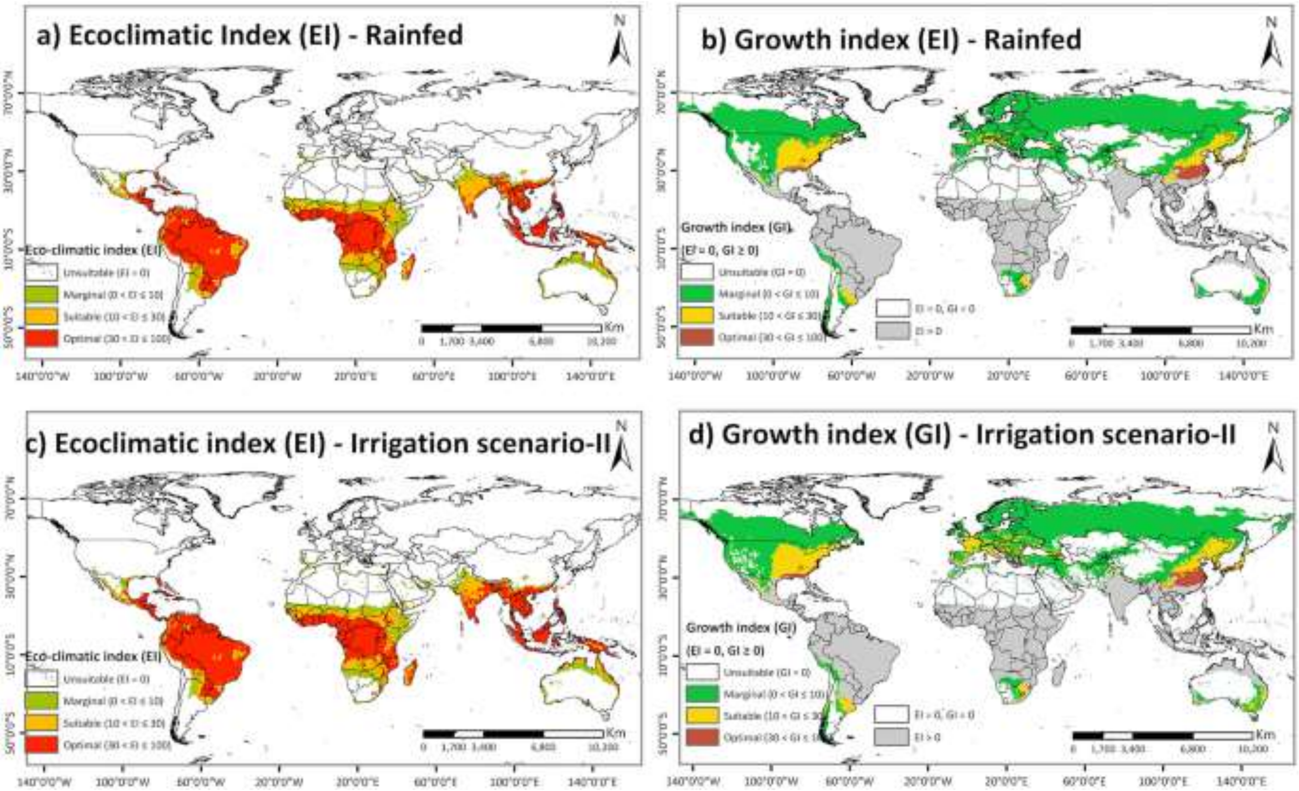
Endemic to the Americas, FAW's rapid spread to West Africa in 2016 triggered agricultural emergencies across more than 40 countries within two years.(CIMMYT, FAOHome)

Entry into Asia

In 2018, FAW was detected in India and throughout Asia, confirmed in at least 13 countries by 2019. It reached Australia by 2020 and Pacific regions in 2021.(Open Knowledge FAO)

Crop Damage & Economic Impact

FAW inflicts considerable yield losses on maize and other cereals, with FAO estimating up to 73% reduction in African maize yields, amounting to around USD 9.4 billion in economic damage.(Open Knowledge FAO, FAOHome)



Common symptoms include "window-pane" feeding on leaves, frass in whorls, dead-heart effects, and ear damage in maize.

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Global Spread and Distribution

Reference :FAO & PPD. *Manual on Integrated FAW Management* (2020) (Open Knowledge FAO)

Climate Change and Expansion Risk

Recent ecological niche modeling predicts that with rising temperatures, FAW could expand further north into Europe and temperate Asia by 2050 (Early et al., 2021). Warmer winters may allow survival in previously unsuitable regions, increasing its global threat potential.

Damage and Economic Impact:

Table 2. Yield losses due to FAW in different regions

Region	Crop Affected	Estimated Yield Loss (%)	Economic Loss (USD)	Source
Africa (SSA)	Maize	15–73%	2.5–6.2 billion	FAO (2018)
India	Maize	30–60%	~1.2 billion	ICAR-IIMR (2019)
Brazil	Maize, Cotton	10–40%	1.3 billion	Farias et al. (2014)
China	Maize	20–30%	~1.0 billion	Li et al. (2020)

Reference : CABI Reviews. FAW sustainable management in rice (2025) (Cabi Digital Library

Management Strategies:

Insecticide Resistance and Resistance Mechanisms

FAW has evolved resistance to multiple classes of insecticides, including pyrethroids, organophosphates, and Bt proteins. Mechanisms include:

- **Target-site mutations** (kdr mutation in sodium channel gene).
- **Enhanced detoxification** via cytochrome P450s, GSTs, esterases.
- **Cross-resistance** between Bt proteins (Cry1F, Cry2Ab).

Case studies in Brazil and the USA demonstrate field-level resistance to Bt maize (Cry1F) within a decade of its introduction (Storer et al., 2010).

Molecular and Genomic Insights:

The complete genome of FAW was sequenced in 2019, revealing high genetic diversity and adaptive potential (Zhang et al., 2019). These insights aid in developing:

- RNAi-based gene silencing approaches.
- Molecular markers for tracking invasive populations.
- Better strain-specific management recommendations.

Socio-Economic Impacts:

FAW affects millions of smallholder farmers in Africa and Asia who rely on maize as a staple. Farmers often spend up to **30% of annual income** on insecticides, sometimes with limited efficacy (FAO, 2019). Beyond yield losses, FAW raises costs of pest management, reduces market supply, and threatens rural food security.

Policy and Institutional Responses:

- **FAO Global Action (2020–2023):** Coordinated global response for FAW monitoring, IPM dissemination, and farmer training.
- **CIMMYT R4D consortium:** Developing resistant maize lines and IPM modules.
- **ICAR (India):** Rapid contingency plans and farmer advisories in 2018–2019.
- **National Programs:** China launched mass monitoring and pesticide stewardship campaigns.

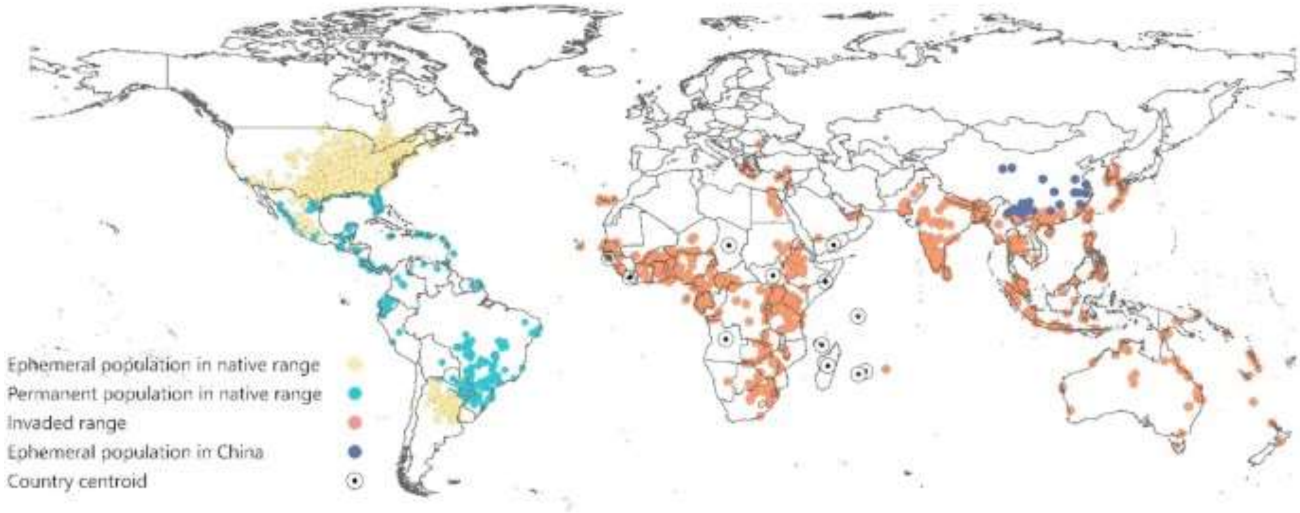
Digital and Precision Agriculture Tools:

FAO FAMEWS App

The FAW Monitoring and Early Warning System (FAMEWS) is a mobile application that allows farmers to upload pest sightings, linked to real-time regional dashboards.

Figures and Tables:

Figure 1. Global spread of FAW from native Americas to Africa, Asia, and Oceania (2016–2021).



Reference :FAO. *Sustainable management of FAW* (FAOHome)

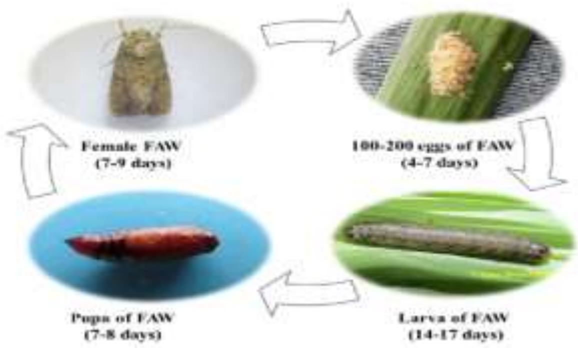
AI and Drone Applications

Machine-learning algorithms trained on FAW damage symptoms are being piloted in India and China for automated pest recognition. Drones are used for precision spraying and pheromone trap deployment.

Research Gaps and Future Prospects:

- Long-term ecological data from Asia and Oceania are scarce.
- Need for **multi-location trials** of resistant maize hybrids.
- More investment in **biocontrol mass-production units**.
- Incorporating **traditional botanical extracts** into IPM modules.
- Strengthening **farmer education** on pesticide stewardship.

Figure 2. Life cycle of FAW showing egg, larval instars, pupa, and adult stages.



Reference :FAO. *Technical guidance on fall armyworm* (2022) (Open Knowledge FAO)

Table 3. Recommended management options for FAW under IPM framework

Management Approach	Examples	Advantages	Limitations
Cultural Practices	Early planting, intercropping, trap crops	Low-cost, eco-friendly	Limited efficacy alone
Biological Control	*Telenomus remus*, NPV, *Beauveria*	Sustainable, self-regulating	Needs mass production
Chemical Control	Emamectin, Spinetoram, Chlorantraniliprole	Rapid suppression	Risk of resistance, costly
Host Plant Resistance	CIMMYT FAW-tolerant hybrids	Long-term, farmer-friendly	May be strain-specific
Digital Tools	FAMEWS app, AI detection	Improves monitoring	Needs connectivity

Reference :FAO & PPD. *Manual on Integrated FAW Management* (2020) (Open Knowledge FAO)

Conclusion

FAW is a complex, migratory, and adaptable pest undermining global food security. No single control method is sufficient; only a well-designed, locally tailored IPM approach can sustainably tackle its threat. Breeding tolerant varieties, reinforcing biological controls, cautious insecticide use, and strong institutional collaboration are vital. Future success will depend on research, farmer engagement, policies, and global collaboration.

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Solar power used by Gujarat farmers

Abstract

This article tells about the renewable energy (solar power) used by the farmers of gujarat enabling sustainable agricultural practices . Solar power has emerged as a transformative energy solution for farmers in Gujarat, enabling sustainable agricultural practices and reducing dependence on conventional electricity. The availability of solar-powered pumps helps to protect the environment by lowering carbon emissions and farmers' dependency on pricey diesel substitutes. Rural communities are empowered by the decentralized nature of solar installations, which increase agricultural productivity and energy access. All things considered, Gujarat's solar projects show how renewable energy can successfully integrate social, economic, and environmental advantages for farmers.

Introduction

Gujarat is a leader in utilizing solar energy for its agriculture sector because of its abundance of sunshine. Growers can ensure effective irrigation while reducing diesel and grid expenses by converting to solar pumps. While kinetic deprescriptions shotanis analysts in Kutch use the sun's heat to pump brine for salt concentration, horticulturists rely on solar dryers and cold storage to increase post-harvest longevity. Dairies power irrigation pumps and chilling machines, and aquaculture operations farther down the coastline benefit from solar-powered aeration and water circulation. Agronomic revenue and energy can be obtained by growing specific crops under solar canopies thanks to the deployment of agrovoltaic systems. When taken as a whole, these solar projects are revolutionizing Gujarati agronomy, promoting sustainability, and strengthening operational resilience.

Uses of solar power in agriculture

•Without using diesel or the electrical grid, solar pumps raise groundwater to irrigate crops. reduces emissions and fuel consumption by replacing diesel pumps.cuts down on or gets rid of costs for diesel and electricity bills. Solar power (remaining) Also used in salt farming in the area of Little Rann of Kutch by spreading brine, or salty groundwater, over a large pan after pumping it to the surface.

•Gujarat farmers use agrivoltaicsSolar power to grow crops + generate power on the same land. Farmers make money by selling excess solar electricity to the grid in addition to their crops.Panel shade lowers evaporation, which helps crops require less watering.Some crops yield 5–20% more when partially shaded. Solar + farming turns unused or barren land back into a productive area.

With the help of solar greenhouses, farmers can cultivate crops year-round, despite changes in the outside weather. The yield and quality of vegetables, flowers, herbs, and high-value crops are increased when the proper temperature, humidity, and ventilation are maintained.provide electricity for greenhouse lighting, heating, and cooling, minimizing dependency on fossil fuels or the grid.Solar greenhouse systems have favorable payback periods and reduce energy costs.enhances crops by offering defense against pests, intense heat, wind, and flooding.minimize the amount of water used.minimizing environmental impact while optimizing yields.

Solar-Powered Dryers used to dry grains, fruits, spices, and vegetables. drying extra produce rather than allowing it to rot or selling it at distressed prices in order to minimize post-harvest losses.Using solar power instead of diesel or electric dryers to save money on energy and keep fungus and pests out.

Challenge faced by farmers

▪ High Barriers to Financing and Initial Investment Many small and marginal farmers find it difficult to secure loans or raise upfront capital, even with subsidies.

▪ Policy Continuity Uncertainty Farmers are concerned about the future stability of purchase agreements, incentives, and subsidies for excess power.

▪ Cooperation with Various Organizations Dealing with banks, government agencies, solar companies, and DISCOMs is often necessary for adoption, which can be daunting for farmers.

▪ Problems with Land Availability Small farmers cannot afford the land or space needed to install large solar panels without compromising crop area.

▪ Administrative Obstacles Farmers are discouraged by complicated paperwork, lengthy approval processes, and delays in subsidy disbursement.

▪ Resistance in Culture and Behavior Despite the advantages, some farmers are reluctant to make the switch to solar due to their traditional reliance on diesel or grid electricity.

▪ Limited Technical and Digital Literacy Many older farmers lack the basic digital literacy needed to monitor solar panels and net-metering.

Advantages

○Free Irrigation: During the day, solar pumps offer dependable irrigation without the need for fuel or electricity.

○Lower Input Costs – Replacing diesel pumps cuts fuel costs and reduces dependence on erratic grid supply.

○ Higher Crop Yields: Prompt irrigation increases output and lowers crop losses.

○ Post-Harvest Benefits: Crop quality is increased and waste is decreased with solar-powered dryers and cold storage.

○Energy Independence: Clean, off-grid energy for pumps, lights, and appliances is available to farmers in remote locations.

○Environmental Benefits: Lowers air pollution and carbon emissions by using less diesel.

○ Land Optimization: Agrivoltaics enables crops to be grown beneath solar panels, utilizing land for both farming and energy production at the same time.

○ Higher Living Standards: Solar pumps lower expenses in salt-growing areas, allowing families to make investments in housing, healthcare, and education. Adoption of renewable energy is encouraged by the Sustainable Future, which makes agriculture resilient and climate-smart.

Disadvantages

◇ Expensive starting price For small and marginal farmers, the initial cost of installing solar pumps and panels can be high, even with subsidies.

◇ The Need for Land Large solar farms and panels take up space that could be used for farming, which is particularly troublesome for small-scale farmers.

◇ Problems with Maintenance Panels must be routinely cleaned and maintained by farmers. Efficiency is decreased by dust storms, bird droppings, or saline conditions (in salt pan areas).

◇ Inefficiency by Season Cloudy weather during the winter or monsoon season lowers power generation, which may have an impact on irrigation schedules.

◇ Limited Technical Expertise Many farmers struggle to deal with malfunctions or breakdowns, which forces them to rely on technicians, who might not be readily available in rural areas.

Conclusion

By using solar power by farmers they are taking a new initiative of modern sustainable farming. farmers' use of solar energy provides a viable and affordable answer for contemporary agriculture. It guarantees dependable energy for irrigation and other farming operations, lowers electricity costs, and lessens reliance on fossil fuels. Farmers who use solar energy not only protect their livelihoods but also help to preserve the environment and build climate resilience.

"A cleaner, more independent, and sustainable agricultural future is made possible by solar power, which enables farmers to harvest not only crops but also clean energy."

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Pusa Decomposer: A Sustainable Solution to Stubble Burning in Indian Agriculture

Abstract

Stubble burning is a recurring environmental challenge in India, particularly in paddy-growing regions like Punjab and Haryana. This journal explores Pusa Decomposer, a microbial solution that enables quick decomposition of paddy residue without burning. The article discusses the biological principles, field usage, benefits, challenges in adoption, and its potential in promoting sustainable agriculture. The aim is to educate students, farmers, and policymakers on how biotechnology can reduce pollution and enrich soil health.

1. Introduction

After the rice harvest, millions of farmers across India are left with huge quantities of paddy stubble. Due to time constraints and lack of resources, many resort to open-field burning — a practice that causes serious air pollution and depletes soil quality. In response to this issue, a fungal-based bio-decomposer called Pusa Decomposer has emerged as a low-cost, eco-friendly solution. This paper highlights how it works, its field-level impact, and the barriers to its large-scale adoption.

2. What is Pusa Decomposer?

Pusa Decomposer is a biological formulation made from a combination of fungal strains capable of breaking down cellulose and lignin found in crop residue. These fungi produce enzymes that accelerate the decomposition of paddy straw in open fields. The product is typically sold in capsule form. When mixed with water, jaggery, and gram flour, it forms a liquid solution that can be sprayed on the stubble. The residue then decomposes within 15 to 25 days, depending on field moisture and temperature.

3. Application Process

The decomposer is easy to prepare and apply:
- Four capsules are mixed with 25 liters of water, along with a carbohydrate source (like jaggery) and a protein source (like besan).
- The mixture is kept for 3–5 days in a warm, shaded area to activate microbial growth.
- Once fermented, it is sprayed uniformly over the crop residue.
- The field is kept moist to support microbial activity.

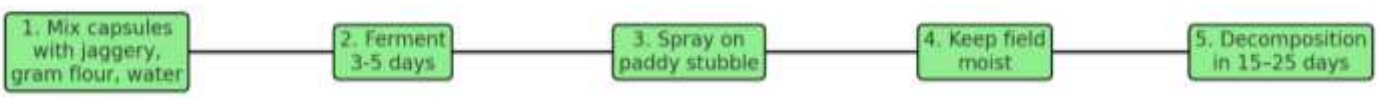
This process transforms stubborn crop residue into organic manure, which improves soil texture and nutrient content.

4. Advantages of Pusa Decomposer

- Eco-friendly: Prevents stubble burning, reducing air pollution and greenhouse gases.
- Soil health: Returns organic carbon to the soil, enhancing microbial life and fertility.
- Cost-effective: Requires minimal inputs; significantly cheaper than mechanical removal.
- Simple technology: Farmers can prepare it themselves with basic materials.

1. **Prevents Stubble Burning**
   - Decomposes paddy straw in the field naturally
   - Reduces harmful smoke and air pollution
2. **Improves Soil Fertility**
   - Converts residue into organic manure
   - Enhances nutrient content and soil structure
3. **Cost-Effective for Farmers**
   - Inexpensive solution using capsules, jaggery, and water
   - Saves labor and machine costs for stubble removal
4. **Eco-Friendly and Sustainable**
   - Made from natural fungal strains
   - Helps reduce greenhouse gas emissions
5. **Enhances Microbial Activity**
   - Boosts beneficial soil microbes
   - Supports long-term soil health and productivity
6. **No Harm to Next Crop**
   - Leaves no harmful residue

Pusa Decomposer: Application Process



- Safe for wheat or other following crops

5. Challenges in Adoption

Despite its benefits, several factors limit the widespread use of Pusa Decomposer:
- Awareness gap: Many small and marginal farmers are unaware of the product or its benefits.
- Time constraints: The rice-wheat rotation gives farmers limited time between crops, and some hesitate to rely on biological methods.
- Training needs: Proper preparation and spraying techniques are essential for effective results.
- Moisture dependency: Decomposition is less effective in dry fields, requiring light irrigation.

6. Field Results and Case Examples

In pilot trials conducted across parts of Punjab, Haryana, and Delhi, Pusa Decomposer showed a visible reduction in stubble within three weeks. Farmers who adopted it reported improved soil structure, less tillage work, and no negative impact on wheat yield. In some areas, state governments distributed free capsules and provided technical guidance, increasing adoption rates.

7. Conclusion

Pusa Decomposer represents a smart, sustainable step toward solving the stubble burning crisis. As India moves toward climate-resilient agriculture, solutions like this can bridge the gap between traditional practices and modern technology. However, for widespread impact, there must be a coordinated effort involving research institutions, agri departments, and rural outreach programs. With proper support, this microbial tool can not only clean our air but also heal our soil.

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AI in Agriculture: Smart Solutions for Pests and Pathogens

Introduction

Agriculture has always been the backbone of human civilization, but now it's at a risk of pests and pathogens which threaten our productivity and food security. In large measure we have turned to broad spectrum chemical pesticides, manual inspection, and responsive measures which in fact are very costly, very time consuming, and also not at all friendly to the environment. With the rising global population and at the same time we are seeing a great demand for sustainability in our food, we are in need of better solutions. AI is utilizing technological methods such as machine learning, computer vision and remote sensing to detect insect and disease threats at an early stage. The inclusion of AI in pest and pathogen management is not simply a step forward in technology but a change of the whole conceptualization of farming systems.

Abstract

The earth is facing the threat of food insecurity every day, and the causes are the change of the climate, the scarcity of the resources, and the biological challenges that keep changing. Hence, the use of AI in farming is a mere necessity rather than a novelty. Conventionally, agriculture has largely relied on using force to solve problems, which include the use of pesticides that negatively affect nature and also the health of the crops.

A New Era of Farming

The heart of the change is basically the use of tech that provides the farmers more info than ever before plus greater control of their systems. An example would be the self-driven drones that have AI-based computer vision as well as a high-resolution camera, in this way they can realize and fly the big fields with supreme exactness. They don't see a field of green; they see pixel by pixel, and can detect subtle discoloration of a leaf, or the shape of an invasive beetle. With this early detection, the application may happen long before the potential outbreak gets out of control.

Cultivating a Sustainable Future

The promise of AI in agriculture is phenomenal. It offers an incredible toolbox for growing more crops, increasing global food production, improving the sustainability of farm businesses for future generations.

We have the opportunity to move out of basically the old reactive way of farming where we just used a lot of resources to a more proactive way of doing things through precision agriculture. AI-enabled implementations can potentially reduce the monstrous dependency on chemical pesticides, and fertilizers that may result in soil predicament, water soil filthiness and most importantly.

Overcoming Challenges and Looking Forward

Though AI has limitless possibilities in the agricultural sphere, the path to its acceptance is still loaded with obstacles. The initial cost for technology is quite high irrespective it being a smart sensor or an autonomous machine which is often the primary reason most small and medium-sized farms are unable to afford it. Moreover, in many areas, there isn't strong internet infrastructure in rural areas to send and process the enormous amounts of data necessary for AI models. Ownership of data, privacy, and the efficacy of farmers being able to develop competence in and manage the systems are also issues that need to be considered.

Precision and Proactive Management

AI's promise is most compelling in agriculture is delivering precision agriculture at scale. Drones, along with ground-based robots, can sweep fields with a degree of focus and speed impossible for humans. They can tell you what early signs of infection by a fungus look like, or if you have a certain kind of insect.

AI's promise is most compelling in agriculture is delivering precision agriculture at scale. Drones, along with ground-based robots, can sweep fields with a degree of focus and speed impossible for humans. They can tell you what early signs of infection by a fungus look like, or if you have a certain kind of insect.

Current Implementation Barriers

The acceptance of AI in agriculture is met with numerous problems that are very tough to solve especially in the case of smaller farming operations. For instance, the high initial costs for sensor networks, imaging equipment, AI software platforms can be so high that many farmers cannot afford them. Besides that, the rural digital divide is still a big problem, and it means that a very reliable high-speed internet is essential for cloud-based AI systems and real-time data processing. There is still a long way to go in the building of the necessary infrastructure in many agricultural regions to support these advanced technologies effectively.

Data Quality and Model Limitations

AI systems are just as efficient as the data they are trained on, and farming environments are difficult-to-handle data domains. Fluctuations in weather, soil qualities, differing varieties of crops and pests living in various regions may cause AI models to have a small number of applications in different areas. The system that is trained with data from mild climate might not be able to work well in hot regions, which can result in the need of a long re-training or localization.

The incessant changes of pest and pathogen populations are another factor that makes the situation difficult. These tiny creatures are perpetually changing and adapting, to the point of possibly becoming resistant to the methods of control or changing their habits. In order to keep them efficacious, AI models need to be adjusted all the time, and that means that there has to be a continuous data collection and model updating.

Promising Future Developments

Still, the utilization of AI in agriculture to combat pests and diseases looks very promising in the long run. One of the developments that can make the access to AI tools more democratic and feasible even in the areas with poor digital infrastructure is the progress in edge computing. It is becoming more and more possible to operate the complicated AI algorithms, which are usually a part of farm equipment, locally without needing a connection all the time.

New platforms, which can integrate different data sources without problems, are becoming available. For instance, it allows combining the data that has been collected with the aid of satellites, drones, ground sensors, and weather stations into one all-encompassing analytical framework. Machine learning methods are getting stronger.

Open data community networks and creative partnering strategies are developing that have the potential to aggregate data and share resources across farming populations. Such projects not only resolve the problem of insufficient data for individual farms but also spread the expenses related to the creation and upkeep of AI systems. Authorities' and institutions' support via programs and extension services for the implementation of AI, in which they provide training and subsidies for the transfer to smart agriculture, is gradually emerging.

The Path Forward

The successful use A.I. to monitor pests and pathogens in agriculture is a huge challenge that requires the collaboration of various stakeholders. First, the tech developers ought to concentrate on designing more user-friendly, and cost-effective solutions that can work efficiently in different agricultural settings. The universities and the extension officers need to create comprehensive training packages that will help farmers comprehend and implement these technologies.

Policy makers should play a major role in this by contributing to the building of the necessary infrastructure, offering the AI adoption incentives, and setting the standards for data sharing and system interoperability. The rural broadband infrastructure will be the base of all cloud-based AI solutions and hence, investment in it will be very essential for the AI solutions to become popular all over the countryside. When these problems are taken care of, AI-based pest and disease management systems will probably be much more accurate, clearer, and accessible. Moreover, such a technology capability to cut down on the use of pesticides and at the same time keep up with the agricultural yields, makes it a foremost component of sustainable agriculture in the future, thus bringing a green light of hope for feeding the ever-growing global population while causing the least environmental damage.

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UNLEASHING THE POWER OF GUAVA: EXPLORING THE FRUIT'S VALUE-ADDED PRODUCTS

Abstract

Guava (*Psidium guajava*), a tropical fruit renowned for its rich nutritional profile and medicinal properties, holds immense potential for value addition beyond fresh consumption. Often termed the "poor man's apple," guava is a cost-effective source of essential vitamins, minerals, dietary fiber, and antioxidants. This article explores the various health benefits associated with guava, including its anti-inflammatory, anti-cancer, and cholesterol-lowering effects. It further examines the broad spectrum of value-added guava products—such as juice, jelly, jam, nectar, shrikhand, blended beverages, pomace, and pulp—which enhance consumer accessibility and market value throughout the year. Through the adoption of innovative processing techniques, guava by-products like peels and seeds are also being converted into animal feed and bio-based materials, contributing to sustainable utilization. The article highlights guava's versatility as a raw material in the food industry and underscores its role in promoting health, reducing post-harvest losses, and opening new avenues for entrepreneurship and rural development.

Introduction

Guava (Psidium guajava) is a nutritious tropical fruit with significant medicinal properties, often called the "poor man's apple" due to its affordability and availability (Kanwa et.al.,2016). The fruit is rich in nutrients and can be consumed fresh or processed into various products such as juice, jam, jelly, beverages, nectar, shrikhand, slices, leather, and pulp (Bhattacharya & Tandon, 2021). Guava processing generates substantial waste, including peels, seeds, and pomace, which can create value-added products like animal feed, essential oils, and nanomaterials (Pathak et.al.,2020). Its unique flavor, aroma, and nutritional profile have made it a favorite among fruit lovers worldwide. Beyond its fresh consumption, guava has been transformed into various value-added products, unlocking its full potential and opening up new opportunities for entrepreneurs, farmers, and consumers.

Guava: A Nutritional Powerhouse

Guava is high in protein, Carbohydrates, Vitamins, minerals and other macro and micronutrients that are renowned health boosters. Guava is an excellent source of vitamins A and C, Potassium, Phosphorus, Iron, Calcium and fiber, making it an ideal fruit for maintaining good health.

Its high antioxidant content has been linked to several potential health benefits, including anti-inflammatory and anti-cancer properties. It also contains polyphenols, flavonoids and Saponins.

Health benefits of Guava

- ✓ Antioxidant phytochemicals such quercetin, carotenoids, vitamin C, and polyphenols are abundant in guava. Their potent antioxidant properties neutralize the body's free radicals and inhibit the growth of cancer cells.
- ✓ A significant amount of dietary fiber, which is necessary for the prevention and treatment of hemorrhoids and constipation, is present.
- ✓ Lower blood cholesterol levels are the result of the enzymes gallic acid, catechins, epicatechins, rutin, naringenin, and kaempferol blocking pancreatic cholesterol esterase.
- ✓ It contains a high concentration of pectin, which reduces blood lipids by delaying meal absorption, minimizing the risk of cardiovascular disease.

Value-Added Products

Value addition encourages the availability of guava beyond of specific seasons and geographical regions and offers customers convenient and inventive products. Since it is 100% edible, has a high vitamin content, and tastes great, guava is a particularly popular fresh fruit. Equally significant to the processing sector is this fruit. There is a vast amount of potential for a variety of value-added guava products, and several cutting-edge technologies have been created for guava value addition. Guava produces a premium natural jelly because it contains a high concentration of pectin. One of the best basic materials for making a variety of other guava products is processed guava pulp. Guava is a nutrient-rich, tropical fruit with various health benefits and is used to develop several value-added products. Here is a list of some of the products

1. Guava Juice
2. Guava jelly
3. Blended Beverages
4. Guava nectar
5. Guava pomace
6. Guava shrikhand
7. Guava jam

1. Guava Juice

Ingredients:

- Guavas-4-5
- Water-2 Cups
- Sugar/Honey-To taste(optional)
- Ice cubes (optional)

Process: Wash the guavas thoroughly. Cut the guavas into quarters, removing any blemishes. Place the guava pieces in a blender. Add water to the blender. Blend until smooth. Strain the mixture through a fine mesh sieve to remove seeds and pulp. Add sugar or honey if desired and stir until dissolved. Serve over ice if preferred.

Storage Conditions: Once opened, guava juice should be consumed within 7–10 days if refrigerated.

2. Guava Jelly

Ingredients:

- Guavas – 4 Cups (Chopped)

- Water- 4 Cups
- Granulated sugar -4 cups
- Lemon juice -2 tablespoons
- Liquid Pectin -1 Package (Pectin)

Process: Wash and chop guavas, removing stems and blossom ends. Combine guavas and water in a large pot, bring to a boil, then simmer for 20 minutes. strain the mixture through a cheesecloth or fine mesh sieve to extract the juice. Measure 4 cups of juice and return to the pot. Add sugar and lemon juice. Bring to a rolling boil, stirring constantly. Boil for about 10-15 minutes or until the mixture reaches 220°F(104°C) on a candy thermometer. If using pectin, add it now and boil for 1 minute. Remove from heat and skim off any foam. Pour into sterilized jars, leaving ½ inch separate. Process in a water bath for 10 minutes.

Storage Conditions: Stored at room temperature for up to 90 days

3. Blended Beverages

Ingredients

- Fresh Guava -2 Cups (Chopped)
- Milk – 1/2 Cup
- Honey or Sugar -2 tablespoons
- Vanilla extract -1/4 teaspoon
- Ice – 1 Cup
- Salt – A pinch

Process:

Wash and chop fresh guavas, removing seeds if desired. Add guava, ice, milk, sweetener, vanilla (If using), and salt to a blender. Blend until smooth, about 30-60 seconds. Taste and adjust sweetness if needed. Pour into glasses and ready to serve.

4. Guava nectar

Ingredients:

- Guavas -4 Cups
- Sugar -1/2 Cup
- Water -2 Cups
- Lemon Juice -1 Tablespoon

Process: Wash, peel, and chop the guavas. Combine guavas and water in a pot. Bring to a boil, then simmer for 15-20 minutes. Mash the guavas and strain the mixture through a fine sieve. Add sugar and lemon juice (if using) to the strained liquid. stir until sugar dissolves. Cool and refrigerate before serving.

Storage Conditions: Guava nectar can last 12–18 months if stored in a cool, dark place. Once opened, it should be consumed within 7–10 days if kept in the refrigerator

5. Guava Pomace

Ingredients

- Ripe guavas
- Water (Optional, for washing)

Process: Wash and clean ripe guavas if necessary. Cut guavas into small pieces. Process the guava pieces in a pulp or food processor to extract the pulp. Separate the pulp from the seeds and skin using a sieve or strainer. The remaining fibrous material (seeds and skin) is the guava pomace.

6. Guava shrikhand

Ingredients

- Ripe guavas – 2-3
- Hung curd -500 g(strained yogurt)

- Cardamom powder – ¼ Cup
- Powdered sugar – ½ Cup
- Saffron – Few strands (if optional)
- Nuts – Chopped (optional, for garnish)

Process: Peel and deseed guavas. Puree the flesh in a blender. In a bowl, whisk hung curd until smooth. Add guava puree, sugar, and cardamom powder to the curd. Mix well. If using, add saffron strands. Refrigerate for 2-3 hours to allow flavors to meld. Serve chilled, garnished with chopped nuts if desired.

Storage Conditions: Shelf life of 35 to 40 days at 8 °C (Anant and Bhadania,2016)

7. Guava jam

Ingredients:

- Ripe guavas – 1kg
- Sugar -750gm
- Lemon juice -2 Tablespoons
- Water – if needed

Process: Wash guavas, remove stems, and cut into quarters. Place guavas in a large pot with just enough water to cover the bottom. Cook over medium heat until soft, about 20 minutes. Mash the guavas or puree them in a food processor, then strain to remove seeds. Return the puree to the pot, add sugar and lemon juice. Cook over low heat, stirring frequently, until mixture thickness (about 30-40 minutes). Test for doneness using the cold plate method or until it reaches 105° (220°F). Pour hot jam into sterilized jars and seal if necessary.

Storage Conditions: In cold storage, the fruit can maintain quality for up to 15 days at 8-10°C and 85-90% RH.

Conclusion

Guava's versatility and nutritional value have led to the development of various value-added products, catering to diverse consumer preferences and needs. As the demand for healthy and sustainable products continues to grow, the potential for guava-based innovations is vast. Embrace the flavor and benefits of guava, and discover the exciting world of value-added products inspired by this incredible fruit!

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Geo-tagging an initiative to conserve Kashmir's iconic 'Chinar' trees

Introduction

The Kashmir authorities have initiated a big operation for geo-tagging almost a thousand of the Chinar trees as part of an initiative to safeguard this symbol of the state. The geo-tagging technology helps conservation of iconic Chinar trees of Kashmir, which are not only an ecological asset but also a cultural symbol of the region. The initiative aims to develop an extensive digital database that will be used to help manage and safeguard the trees, which are at risk because of urbanization, infrastructure development, and diseases.

Goe-tagging includes addition of geographical identification metadata to photographs, videos, or other data formats. For Chinar Tress, It means assigning exact GPS coordinates to each tree. This is done to create a digital inventory and monitoring the health and distribution of trees across the region.

Cultural and Ecological Importance of Chinar Trees:

Chinar trees (Platanus orientalis), or as referred to locally as Booune, are not only majestic elements of the landscape of Kashmir but beautifully a part of the cultural and historical fabric of the region. Chinar trees are renowned for being huge, having deep red foliage during autumn and living for hundreds of years. It provide shade, help in carbon sequestration, support biodiversity and prevents soil erosion. However, the population of Chinar trees has come down significantly over the past few decades due to:

•Boosting urban infrastructure
•Road-widening projects
• Natural diseases and neglect

Graphs showing reduction of Chinar trees in Kashmir

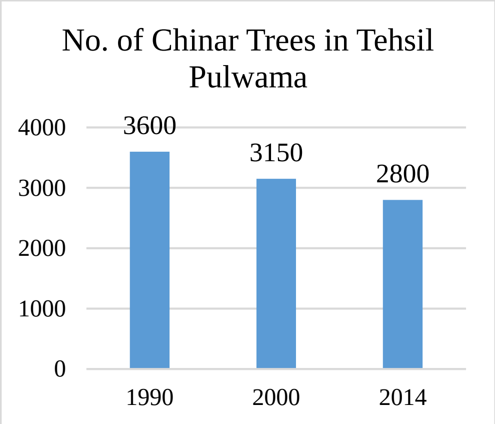

Fig. Reduction of Chinar Trees in Tehsil Pulwama Since 1990

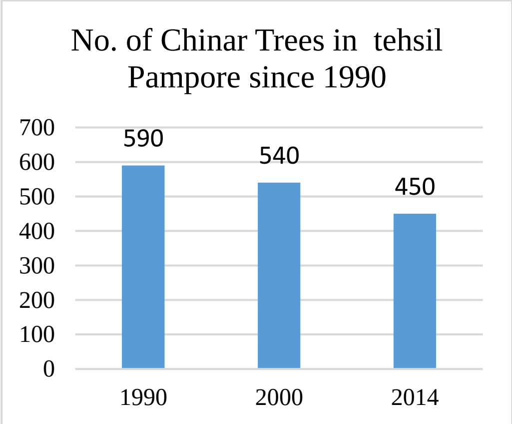

Fig. Reduction of Chinar Trees in Tehsil Pulwama Since 1990

The Geo-Tagging Initiative:
The initiative involves the use of technology to attach QR codes to each Chinar tree. These codes store detailed data about the tree, including following 25 parameters:

S. No.	Parameters	Description
1)	GPS Coordinates	Shows the latitude and longitude of the tree's exact location
2)	Altitude	Shows the elevation above sea level
3)	Tree ID/Tag Number	It is the unique QR or code identifier
4)	Species Name	Scientific Name (e.g., Platanus orientalis)& Common Name
5)	Age Estimate	Shows the estimated age of the tree in years
6)	Growth Stage	Shows the developmental phase: Sapling, young, mature, or senescent
7)	Tree Height	Shows the total vertical height (in meters)
8)	Trunk Girth	Shows the circumference at breast height (CBH)
9)	Canopy Diameter	Shows the width/spread of the crown (in meters)
10)	Health Status	Condition category: Healthy, moderate stress, critical, or dead
11)	Visible Pests or Diseases	Any signs of fungal infections, bark disease, etc.
12)	Leaf Condition	Observations on colour, dryness, or deformities
13)	Trunk Condition	Presence of cracks, hollows, cavities, or fungal growth
14)	Branch Structure	Uniformity, strength, and breakage risk assessment
15)	Root Exposure	Whether roots are visible due to erosion
16)	Soil Type	Type of soil: Sandy, loamy, clayey, etc.
17)	Soil Moisture Content	Classification as wet, moist, or dry
18)	Surrounding Vegetation	Type of flora present in the vicinity
19)	Proximityto Infrastructure	Nearby roads, buildings, electrical wires, etc.
20)	Environmental Stressors	Threats like pollution, flooding, or nearby construction
21)	USG Internal Assessment	Signs of internal decay, hollowness (using ultrasonic or other methods)
22)	Fire Damage or Risk	Evidence of fire scars or vulnerability to fire due to dry litter
23)	Lightning Strikes (if any)	Records or signs of past lightning strikes
24)	Risk Level Rating	Categorized as low, medium, or high based on cumulative factors
25)	Maintenance/Intervention Needed	Any required action like pruning, treatment, or protection measures

So far, around 29,000 trees have been geo-tagged, with more, especially smaller ones are set to be included in the near future.

Source: https://www.reuters.com

Public Access and Conservation Tracking:
The QR codes make it possible not only for

conservators but also for the public to scan the codes using smartphones and gain vital information about specific trees. This introduces an element of transparency and public involvement in the conservation process. Further, the information allows for better tracking over time and makes it possible for authorities to:

•Track decline in health.

•Detect disease early.

•Plan interventions more effectively.

•Avoid accidental destruction by way of development activities.

Use of Ultrasonography-Based Gadgets:

In addition to the above, the project employs a USG-based (ultrasonography-based) equipment. This equipment identifies internal risk factors in a tree, including rotting or hollowing, automatically. This cutting-edge method:

• Reduces the necessity for manual inspections

• Provides objective, data-driven insights

• Helps prioritize conservation resources efficiently

Heritage Trees and Their Impressive Lifespan:

Chinar trees are famous because they have a long lifespan. They develop fully in around 150 years, reaching the **height** of **30 metres** and developing a **girth** of **10 to 15 metres**. The most ancient Chinar tree, situated near **Srinagar**, is around **650years** old, representing not just endurance but also deep-rooted history. . It is a witness to the survival of this tree in the face of political, environmental, and human transformation.

Source: https://www.ndtv.com (**A 380-year-old Chinar tree in Nishat Bagh)**

Development Pressures and the Requirement of Balance:

Though the region has witnessed a decrease in conflict during the past few years, the peace itself has brought about an influx of development projects and tourism. All these developments, though fruitful for the economic progress of the region, threaten to cause harm to Chinar trees unless there are environmental protection measures such as this geo-tagging campaign in place to promote balanced and sustainable development**.**

Conclusion: A Blend of Technology and Tradition for Sustainability:

Geo-tagging the Chinar trees of Kashmir is an innovative approach to preserving heritage. It renders cultural protection technologically compatible. While seeing the authorities attempt to preserve one of Kashmir's most recognized natural features while being able to provide necessary development. This is a powerful precedent for environmental heritage protection through data-driven, inclusive policies. Further this model could become model for conserving other endangered plant species in India. Also act as climate resilience and urban forestry effort. Community participation can be encouraged through awareness and education.

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"REVOLUTIONIZING VEGETABLE FARMING THROUGH PROTECTED CULTIVATION"

Introduction

Protected cultivation or controlled environment Agriculture (CEA) is a cropping technique where controlled micro-climate influences the growth and development of a plant

"**Protected cultivation maybe refers to as a process of growing plants/crops under controlled area**."

Where, controlled means to regulate

We can regulate many factors in protected cultivation such A biotic and Biotic factors

A biotic factors ie;-

- Light
- Temperature
- Soil born disease
- Nutrient
- Hormones
- Rainfall
- Ventilation

Biotic factors ie:-

- Microbes
- Humans
- Animals
- Plants
- Insect & pest

[1]. The essential factors such as temperature, humidity, light, and others, are regulated as per the requirement of the crop. Green house, polyhouse, shade net house and low tunnels are the different types of protected cultivation structures commonly adopted by the Indian farmers [2]. A poly house is a framed structure made of transparent or translucent low-density polyethylene that has been UV stabilized to a thickness of 200 microns (800 gauges). This polyethylene generates a greenhouse effect that makes the microclimate ideal for plant growth and development [3]. A shade net house is a framed building composed of bamboo, angle iron, wood, or GI pipes. It is coated in plastic net, which is composed entirely of polyethylene thread and has been specially treated with UV light to provide varying degrees of shade.

It provides crops developing within such a largely controlled climate and environment by lowering daytime light intensity and effective heat. Thus, throughout the year seasonal and off-season farming is feasible. In tropical and subtropical regions, shading nets are utilized for the production of vegetables [4,5,6] Indian farmers are increasingly adopting the practice of cultivating vegetables under covered structures, particularly those with smaller land holdings [7]. Opting for protected cultivation, the productivity of vegetable crops can be increased by 3 to 5 times as compared to open environment [8].

Need of Protected Cultivation

In regions with severe weather, scarce land and water resources, and dense populations, protected agriculture is crucial to satisfying the growing demand for high-quality horticultural produce. Additionally, it makes it possible to grow crops all year round and in off-seasons, which can boost farmers' revenue and job prospects. India is second largest after China in vegetable production of 113.5 million tons. However annual requirement of vegetables is estimated to be about 135 million tons by the end of 2020. Low production and productivity of vegetable has been attributed to the extremes of temperatures ranging from 0 to 48°C during the year [9]. Use of water is optimized and there's reduction in the consumption by 40-50% [10]. Reduces diseases, pests and viruses due to biotic stress during rainy and post rainy season. Increasing demand of high-quality vegetables Some of the objectives of protected cultivation are:

- Protection of plants from biotic and abiotic stress
- Minimal weed infestation and effective use of water.
- Enhancing productivity per unit area
- Minimising the pesticides use in crop production.
- For control P^H
- For Irrigation Control
- For minimize the soil born diseases

Why, Need Of Protected Cultivation ?

The production of vegetables in open fields is hampered by a number of factors, including high insect pest infestation pressure, fungal diseases **(Sringarm *et al.*, 2013**), heavy rain, thunderstorms, excessive solar radiation, temperatures, and humidity levels above plant growth optimums. According to Trivedi and Singh , the main determining element in horticulture crops is the environment. Protected cultivation is utilised to reduce the impact of the environment. The sustainable method for growing vegetables in unfavourable weather is protected cultivation. In addition to being shielded from harsh weather conditions, vegetables grown in protected areas produce vegetables of superior form, size, and colour . It is possible to alter the microclimate inside the polyhouse. A UV opaque covering material for poly houses helps to prevent insects from entering the house because some insects need UV light for their eyesight purposes. As a result, insecticide usage is minimal. Due to the favourable interior microclimate and greater price, vegetable production is higher than in open fields. The term "protected cultivation" refers to a variety of tools and techniques, such as windbreaks, irrigation soil mulches, etc., as well as buildings like greenhouses, tunnels, and row covers that alter the surrounding environment to increase productivity year-round **(Trivedi and Singh, 2015).** It will further extend the harvest season, boost yield, improve quality, and maintain frequent availability of commodities. It is a standard production strategy that relies on tillage, manure, fertiliser application, and irrigation timing to control the kind of root medium. Light, temperature, air quality, and relative humidity have no bearing on crop production in an open field situation. One of the solutions for the aforementioned factors is greenhouse production.

Importance of Protected Cultivation

- High Production: When A biotic & Biotic factors are in our controlled, the production will be automatically high.
- Continuously food supply.
- Off season cultivation.
- Solution of flood and rainfall area.
- Green House are being commercially used for production of Exotic off season vegetable, Export quality of cut flowers and also used for raising quality seedlings.

1. **There are various types of protected structures based on soil & climate used for vegetable cultivation.**

1. <u>Climate Controlled Greenhouse</u>

In order to produce crops with the best development and productivity, greenhouses are framed or inflated buildings coated in transparent or translucent material that are large enough. These are best suited for year-round growing of high value commodities like vegetables and flowers. The greenhouse is equipped with cooling pads and exhaust fans in the summer to reduce the temperature. Heaters are offered in the winter to increase the temperature. The allowable range for the night time temperature is 12–13^{0}C.

2. <u>Zero Energy Naturally Ventilated Greenhouse</u>

The shielded structures without climate control equipment are known as naturally ventilated greenhouses. Through insect-proof netting, mostly at the top and sides, it is naturally ventilated. They are basic, reasonably priced greenhouses with a manually operated system for natural ventilation. These greenhouses can be used safely and effectively to grow cucumber, tomato, and capsicum all year long for 8 to 9 months.

3. <u>Shade Net House</u>

Perforated plastic shade nets are used to block sun radiation and stop the scorching or wilting of leaves brought on by rising temperatures. Shade net's primary goal is to somewhat reduce temperature and radiation during the hot summer months of May through

September. Shade nets are offered in a variety of shade levels, from 25-75%. Shade net homes are suited for locations where the average daytime temperature is 28–30oC and the night time temperature does not fall below 15–18°C.

4. Insect-Proof Net House

It can be created as a temporary or permanent building and is inexpensive. The building is covered in a 40–50 mesh UV–stabilized insect– and rust–resistant nylon or metal net.

primary function of the building is to act as a barrier against the entry of disease-carrying insects and other pests. Pesticide consumption is reduced in fresh vegetable cultivation while using insect-proof net houses. Tomato, chilli, sweet pepper, and other crops can be raised using this technique, but in order to grow them in insect proof net houses, it is necessary to cultivate virus-free, healthy seedlings of the crop either in a greenhouse or by covering the nursery beds with insect proof net.

5. Tunnels: Tunnels are basically two types

A. Walking Tunnel

B. Low Tunnel

A. Walk-In-Tunnel

Walk-in tunnels are transparent UV stabilised (150-200 micron) polyethylene walls covered in GI pipes, plastic pipes, or bamboo that are bent semi-spherically. The centre is kept between 6 and 6.5 feet in height and 4.0 and 4.5 feet in width. Depending on the situation, the structure's length may change. The walk-in tunnels are simple to put together and take apart thanks to the use of prefabricated structures. Nut-bolts are used to assemble the entire structure; welding is not necessary. Walk-in tunnel constructions are made to support trellising loads of 15 to 25 kg per square metre

B. Low Tunnels

Low tunnels are pliable, transparent covers placed above GI wire hoops. The hoops are covered with or stretched over transparent plastic that is 25–50 microns thick and 2 m wide. The sides are then fastened by burying them in dirt. Low tunnels are transient and often do not rise over 1.0 m. The flexible galvanised iron hoops (4-6 mm thick) are manually fastened at a distance of 3–4 m on trenches immediately following sowing. Keep the hoop's two ends' width to 1.0 metres. Row length can vary based on the situation.

3. System of production for vegetables grown protected cultivation under

3.1 Geoponics or soil system: Crops are produced on natural soil under protected cultivation under this approach. Its drawbacks include an increased risk of disease and insect infestation in the soil. But by far the most often used cultivation system is this one

3.2 Soilless cultivation: Since nearly methyl bromide is used as a soil disinfectant in between crop cycles, the adoption of the soilless farming technology has grown dramatically in the last several decades **(Krishna *et al*., 2023).** In a similar vein, a growing variety of substrates are being developed with the aim of improving quality and production for plants cultivated in soil. A variety of substrates are employed as soilless media to shield crops from various soil illnesses, including coconut fiber, perlite, vermiculite, rock wool, peanut hulls, rice hulls, and coco peat. Compared to agricultural soil, the solid components of soilless growth media (hydroponics and aeroponics), either alone or in combinations, may offer a better environment for plants. To cultivate Indian veggies using this approach, there isn't a sufficient resource available, thus most farmers end up cultivating "exotic vegetables" with imported seeds. The carbon footprint of what is supposed to be a low carbon farming approach is increased because many of the parts needed to construct these growth systems must also be imported. Currently, India imports over 85% of its exotic vegetable production, resulting in an annual growth rate of 15-20%.

3.3 Temperature maintenance: While a variety of crops may be produced in a broad range of temperatures, each crop needs a particular range of temperatures for optimal growth and development. Under protected cultivation, it's feasible.

4. Training and Pruning Methods in Protected Cultivation

➢ **4.1 Training:** Training is the process of giving a plant a specific form by stalking, tying, or supporting it in a specific way over a trellis or pergola, or by removing or trimming some of its parts. Training describes the methodical elimination of parts to create a suitable shape for the plant that can support a big crop load.

➢ **Objectives**

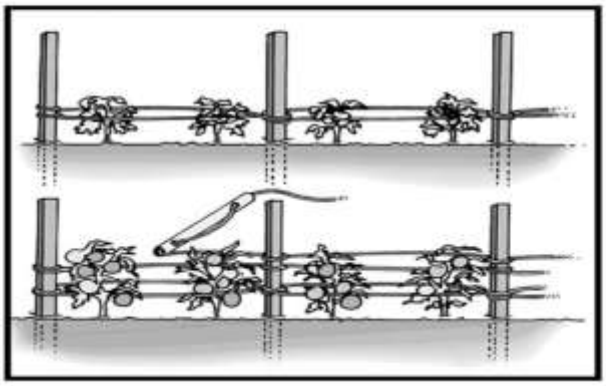
• Regulates the form of plants.

• Proper distribution of fruit-bearing components

• Insect and disease control

• Make it easier for sunlight to be reflected off of every component of the plant.

• Create a balance between a plant's vegetative and reproductive growth.



➢ **Principles**

• Training should begin at the very young age of the plant;

• In plants with considerable apical dominance, the terminal bud should be removed to encourage the growth of side branches.

• Drooping branches need to be removed.

➢ **4.2 Pruning**

Pruning is the process of removing any extra or unneeded/unproductive branches, shoots, or other sections of a plant in order to allow the remaining portion to grow properly or in accordance with the pruner's preferences.

➢ **4.3 Prudent**: Removal of portions, such as roots, leaves, flowers, fruit, etc., to provide a good and high-quality harvest.

➢ **Objective**

• To eliminate weak shoots and diseased, damaged, or insect-infested portions of the plant.

• To thin out fruits and flowers

Table 1. Crops grown under protected cultivation

Vegetables: Tomato, coloured capsicum, (yellow and bell peppers), Cucumber, Broccoli, red cabbage, Leafy vegetables, Radish etc.

Period/ crop cycle

Crops	**Transplanting**	**Harvesting**
Tomato	AUG- Sep	Apr-may
	Apr-May	July -Aug
	February.	May - June
Cucumber/Leafy vegetable/Okra /cauliflower	Nov-Dec April-May	March-April October-November

5. Criteria for Crop Classification for Protected Cultivation

Most suitable for sheltered cultivation are vegetable crops with a high value, limited shelf life, and tiny size. Cucumber, tomato, and sweet pepper are grown throughout India, especially in the hills. But green vegetables can also be grown in sheltered environments. At high altitudes, it is possible to produce vegetables like cabbage, cauliflower, tomato, brinjal, capsicum, beans, peas, and coriander **(Kumar *et al.*, 2020)** well under protected conditions.

6. Individual Crops' Responses to Protected Cultivation

6.1 Tomato: For a high production and superior quality, tomatoes need a comparatively chilly, dry environment. Pollen bursting problems arise at temperatures below 10°C, whereas higher temperatures cause tomato fruit drops prematurely. The decreased temperatures mostly had an impact on agricultural productivity because of problems with fertilization and lower fruit output. Fruits with thigh temperatures are sometimes severely damaged or distorted, making them unmarketable, while red types typically turn more orange. If the temperature in the protected cultivation is maintained, these issues can be resolved. Poor fruit set results from temperatures above 30°C because they might dry up the stigma and pollen grains.

6.2 Coriander: In a naturally ventilated polyhouse, coriander establishes and grows effectively, producing more biomass, according to Isaac S.R. Cucumber: Growing cucumbers in PE bags with sand, perlite, and volcanic scoria as substrates produced better results than growing them in soil. According to (Singh *et al*.,) the most practical and cost-effective greenhouses for growing cucumbers year-round in India's northern plains were those with natural ventilation.

6.3 Sweet pepper: In a greenhouse with natural ventilation and little energy consumption, it may be cultivated effectively. One of the most often produced vegetables in greenhouses, capsicum has better yields.

7. Scope of Cultivating Vegetables under Protected System

By the end of the 20th century, there were over 100 ha of greenhouse space in Asia and over 275,000 square feet worldwide **(Kang *et al*., 2013).** India’s protected agriculture landscape Indian horticulture has a vast range of applications in India. the following promising fields have a lot of potential for protected cultivation:

7.1. Cultivation in an unfavorable agro climate: Most of India's uncultivated land is beneath unsuitable terrain, such as deserts and dry, uncultivated fallow regions. For the locals, even a little percentage of this land turned over to greenhouse farming might result in large financial gains.

7.2. Greenhouses surrounding large cities: Fresh vegetables and flowers are in high demand all year round in big cities. Large cities also have a need for expensive and off-season crops, Greenhouse cultivation is therefore encouraged to meet urban needs.

7.3. Export of farming turn out: Globally, agricultural products—especially cut flowers—have a sizable market. Export promotion would surely benefit from protected export-oriented commodity production and greenhouse farming **(Pattnaik & Mohanty, 2021).**

7.4. Greenhouses (GH) for plant propagation: Nowadays, greenhouse technology is considered a suitable method for growing seedlings and cuttings that require a controlled environment for their development. The GH facility may improve the product's production quality and capabilities **(Patil *et al*., 2023).**

7.5. Biotechnology greenhouse technology: Tissue culture materials ought to proliferate rapidly. Aquiculture or Nutrient Film Technique (NFT) is needed to provide controlled environmental conditions for plant growth

7.6. A greenhouse for the growth of unusual and medicinal plants: Several distinctive species, such as intensively grown orchids, and other medicinal herbs may be found in India. The greenhouse may give the perfect kind of environmental conditions for the intensive production of some plants.

8. Significance of Cultivating Vegetables under Protected System

- Due to the availability of the necessary plant environmental conditions, four to five crops can be cultivated in a greenhouse throughout the year.
- Produce of superior quality can be acquired since it

is cultivated in an appropriately managed environment.

• In a greenhouse, equipment for the effective use of various inputs, such as water, fertilizer, seeds, and plant protection agents, can be well-maintained.

• Because the growing area is enclosed, pest and disease management may be done effectively.

• A large percentage of seedlings germinate in greenhouses.

• Plantlets can be acclimated using the tissue culture approach within a greenhouse.

• Crop production timetables for horticulture and agriculture can be arranged to take advantage of of the market needs

• Peat mass, vermiculate, rice hulls, and compost— different types of growing medium used in intensive agriculture— can all be used successfully in greenhouses.

• Produce of international standards and export quality can be grown in greenhouses.

• Using the trapped heat, it is possible to dry gathered produce and do associated tasks when the crops are not being produced.

• Using computers and artificial intelligence techniques, greenhouses can be automated for irrigation, application of other inputs, and environmental controls.

• Self-employment for young people with education

9. Future Thrust

Protected agriculture will help educated unemployed youth find many opportunities for self-employment, but it will also strengthen the national economy by promoting the sale of premium produce in both domestic and international markets **(Choudhary & Verma, 2018)**. In addition to providing excellent water and nutrient consumption efficiency, enclosed vegetable production has the potential to increase productivity over open field agriculture by a factor of three to five under the country's varied agroclimatic conditions. This technique has great potential, especially in the peri-urban and metropolitan areas around the country's major cities, which are becoming a fast-growing market for fresh produce.

Vegetable farming utilizing agribusiness models, the targeting of many specialized markets in the nation's main cities consistently draws the attention of vegetable producers, encouraging them to move from traditional crop-growing methods to such new alternatives. The warm, sunny days and cool nights in the hot, arid region of India, despite several challenges, make it an ideal place to cultivate cucurbits, including cucumber, watermelon, muskmelon, longmelon, bottle gourd, ridge gourd, tinda, summer squash, etc. **(Meghwal *et al.,*)**. Under such conditions, cucurbit cultivation yields a meager yield of inferior product. The poor output of cucurbits in hot, dry areas can be enhanced by utilizing innovative techniques including drip irrigation and fertigation, low tunnel technology, spraying micronutrients, and integrated crop management (ICM). Vegetables are still usually cultivated with little technical input, thus new methods like tunnel cultivation are needed to increase output, productivity, and cucurbit quality. Low tunnel technique has the potential to increase the profitability of cucurbit agriculture during the off season. The utilization of inexpensive covered structures, especially low tunnels with little alterations, may become an alternative for the effective development of cucurbits in dry conditions.

10. CONCLUSION

Protected crop production is a good technique for the agricultural community since it is a financially worthwhile endeavour. It is safe to consume the veggies because less chemicals are used in their cultivation. A friendly atmosphere for off-season growing and excellent results are also provided by this strategy. The rising demand for vegetables from a growing population and for sustainable food security may thus be met by this technology through long-term production systems.

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Greenhouse Cultivation

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Introduction:

The principle of controlling the crop's microenvironment is essentially what the phrase "green house" refers to. Usually shaped like a house, it may be adjusted to provide the right amount of natural light, humidity, temperature and even greenhouse gas concentrations to suit the needs of a specific crop. The most intensive type of commercial farming, known as "food factories," is greenhouse technology. Greenhouse vegetable production leverages technological advancements to optimize crop yield and elevate the quality of vegetable products by controlling the environment. Greenhouses are the most effective way to overcome climatic diversity. Small growers may find that protected cultivation meets their needs since it can greatly boost productivity while also improving crop quality.

Principle: The basic ideas of protected agriculture are ventilation for cooling and air CO_2 management and the greenhouse effect for heating planted space utilizing sunrays. The planted area is sealed off and coated with glass or plastic film that traps heat by being partially opaque to long-wave infrared radiation emerging from the soil, plants and structural surfaces but transparent to incoming short-wave radiation from the sun impinging on the outside surface. Enclosed spaces so maintain a temperature that is higher than the surrounding air. Trapped heat, however, eventually escapes through radiation, convection/ventilation, and conduction. Heat sinks, decreased airflow, and the use of radiation shielding either slow down the rate of cooling or add another heat source within.

Important considerations for successful protected cultivation

The expanding greenhouse horticulture subsector offers marginal land usage, appealing financial options and chances to preserve the environment. Compared to current open-field cropping, the technology is far more advanced, necessitating a great deal more care and precision as well as greater start-up and operating expenditures. A number of greenhouse horticultural considerations need to be taken into account when determining how much time, money, and effort to invest. These include:

1. Economics
2. Ecology
3. Technology
4. Physical infrastructure
5. Labour

Important aspects to be kept in mind before undertaking protected cultivation of Horticultural crops:

- Climate of the place.
- The crop to be grown.
- Resources to undertake protected cultivation.
- Knowledge of government support schemes of protected cultivation.
- Market for selling of quality produce

Selection of vegetables:

The size of the structure, crop production economics and profit margin all influence the vegetable crop that is grown in a greenhouse. In an expensive greenhouse, any crop can be cultivated at any time; in a typical low-cost greenhouse, the selection of crops is more important. The practice of growing high-value vegetable crops including tomatoes, cucumbers, chillies and capsicums in greenhouses is gaining popularity. Compared to an open field, a greenhouse requires more labor and other inputs per unit area. Fresh vegetables are in high demand all year round in big cities. Tomatoes grow rather well in protected environments.

1. Economics:

1.1 Cost: Greenhouse horticulture involves huge start-up costs, due to the structures presently used. However, attempts have been made by farmers having less resources, to find more affordable yet effective structures, including the use of local timber/ bamboos.

1.2 Capital: Lot of initiatives have been taken up by Government of India to promote protected cultivation through various schemes like National Horticulture Mission, *Rashtriya Krishi Vikas Yojna*. Under these schemes, farmers are provided with 50% subsidy and even more at State level e.g. 65 to 75% in Gujarat.

1.3 Market: Most markets require a steady supply of high-quality produce, which greenhouse horticulture provides. A thorough marketing policy needs to be put into place in order to lower transportation costs, stable prices and provide the market in particular, the large supermarket chains that are becoming more and more common in metropolitan areas with products that are labelled and quality-certified. Large retail groups are increasingly included precise growing standards for the environmentally sound development of healthy commodities in their contracts with large producer organizations

2. Ecology

Greenhouse horticulture was developed in the temperate countries to conserve heat for growing plants during cold periods. In the Tropics, this feature limits the use of the technology, giving tropical protected horticulture some markedly differing needs. Key ecological factors involved include solar radiation/ temperature, water, wind, relative humidity, flooding and pests.

2.1 Solar radiation: The mean daily total of solar radiation energy for each month is crucial for crop output and plant growth. This will give the required details regarding the variation in the average daily total solar radiation over any two-month period. With the use of this information, appropriate greenhouse equipment can be planned to regulate solar radiation in a way that benefits crops grown beneath it by adjusting the amount, length, and quality of light. The lowest daily radiation required for a plant to grow sufficiently is 500–1000 Wh/m2/day. In order to properly utilize the high mean daily radiation in tropical regions, cultivars appropriate for shorter day lengths must be selected.

2.2 Temperature: For greenhouse technology the temperature should be considered in two different ways. First, the outside temperature on which the structural design of a greenhouse depends. Second is the inside temperature, which is modified in favour of the crop grown under the greenhouse.

2.3 Water: Greenhouses keep out rainfall, thus requiring a consistent supply of adequate quality water for efficient crop production. This water should be free of excessive solid particles (e.g. soil, algae) and a pH level of 6.5 to 7.2. For instance, tomato and sweet pepper plants use an average of 1.5 -2 litres water per day. Sufficient volumes must therefore be calculated for the duration of drought periods and appropriately-sized storage facility constructed. Significant volumes of rainfall can be harvested from the roof of greenhouses.

2.4 Relative humidity: The importance of air humidity for designing greenhouse for crop production is frequently underestimated. Both the humidity of air outside and inside of a greenhouse shall be meticulously evaluated and considered while planning a greenhouse. Furthermore, both absolute humidity and relative humidity has to be properly measured and shall be considered with due importance. Plant growth and production will slow down or stop when the humidity in air is lower than 30% or higher than 90%.

3. Technology:

3.1 Selection of variety: There are three aspects for crop selection for farming under greenhouse. These aspects are guided by combined output of some information.

1. The market, growing habit (vine or indeterminate), differential capacity to improve yield in comparison to open field, off-season production, greenhouse status and climate control system all influence the choice of crop.
2. The selection of crop groupings depends on the climate and the crop's physiological potential for increased output.
3. The choice of crop type is determined by practical viability, consumer desire and genetic capacity.

3.2 Selection of growing media:

Soil-based root media: Most of the greenhouses for crop production use soil-based media. Traditionally, the soil-based medium is composed of equal parts by volume of loam field soil, coarse sand, rice husk and well-decomposed organic matter adjusted to proper pH level.

Soil-less root media: In initial stages of greenhouse cultivation, particularly in crop specific greenhouse, soilless root medium is popular for the following reasons:

1. Proper field soil is not available, and transportation of soil is not feasible.
2. Maximization of production through highest possible supply of nutrient, air and water to the media.
3. Reduce the weight of the medium (for potted plant) to suite the pot for long distance market and
4. Perfect application of automation in the greenhouse.

3.3 Pasteurization or fumigation of growing media: It is now a must-have procedure for all greenhouses. Nonetheless, there is a greater potential for the formation of disease-causing organisms in warm climates where the greenhouse's interior environment does not freeze, the humidity is high and the temperature is higher. In a greenhouse, the continuous culture of a single crop or a cycle of several crops offers a constant host for the growth of disease-causing organisms. The previously mentioned factors further exacerbate the nematode problem. Soil solarization, any appropriate chemical or steam injection can all be used to achieve pasteurization.

3.4 Drip Irrigation: It is the most effective way to cultivate any type of horticulture crop in a greenhouse or an open field. One of the main issues with drip irrigation systems is clogging, which may be prevented with careful monitoring throughout system installation and operation. In addition, the following has to be attended to. Water analysis not only provides information about how well a crop can use it, but it also provides insight into potential clogging issues in drip irrigation systems. Therefore, it is imperative to assess the water quality prior to planning the construction of a drip irrigation system.

3.5 Fertilizer application and fertigation in greenhouse (Constant feed, Intermittent feed): Maximizing the benefits of fertilizer in terms of plant growth or output is essential in a greenhouse. The ideal approach to provide plant nutrients—naturally or with chemicals—so that the plants can utilize them is called fertilization. Using a drip irrigation system, there are two primary ways to administer liquid fertilizers containing specific plant nutrients to greenhouse plants.

3.6 Crop Protection: Maintenance of crop health is essential for successful farming for both yield and quality of produce. Pest Monitoring measures such as sticky traps should always be in place for timely action. Unwanted visitors should be discouraged from entering the greenhouse. GAP (Good Agricultural Practices) should be adopted to protect the crops from pests.

3.7 Canopy management: It is the procedure whereby a plant is regularly pruned to provide it with a certain, enduring structural framework. In reality, a plant's direction and spacing of some branches or its main stem are controlled by pruning or other means so that they form a suitable framework that lets in more light and airflow. In order to allow for high density planting, this lowers the land area covered by the plant canopy and boosts biomass efficiency.

3.8 Tools and equipment: Much higher levels of efficiency will be possible with the usage of specialized tools and equipment. The condition of the greenhouse environment can be determined by using items like meters to measure temperature, relative humidity, light, pH, electrical conductivity, and plant nutrients. These meters can also be used to advise management decisions that will better suit the plants. The ultimate form of computerization is completely automated systems that enable effective control of larger facilities even from a distance through satellite or telecommunications technologies.

4. **Physical infrastructure:** 1**.** Roads 2. Energy 3. Engineering facilities

5. Labour: The competencies required for conventional open field operations are very different from those required for greenhouse horticulture. This has to do with how often, when, and how detailed operations are. Additional tasks (such as more thorough pruning, trellising, pollination, measuring PH and electrical conductivity (EC), and taking care when utilizing double doors) as well as more technical abilities are required. Numeracy and literacy are essential for maximum productivity. Due to their devotion and superior attention to detail, women are typically better suited for the majority of operations. The viability of relevant and suitable buildings for the production of vegetables is primarily dependent on the local climate. Despite this, selecting these structures also depends on a number of other considerations, such as a farmer's financial situation, the availability of a guaranteed market and electricity.

The following are the major protected cultivation methods in vogue:

1. Mulching
2. Floating Covers
3. Low tunnels / Row Covers
4. Cloches
5. Polyhouses / Greenhouses

Mulching: Covering the soil around cultivated plants is a common method to improve the growing environment for plants. This includes preserving soil moisture, keeping the soil temperature higher, weed control, and maintaining a more friable root zone that promotes soil aeration and root growth. Depending on the intended effects and climatic conditions, covering materials can be synthetic (polyethylene and PVC) in various colors (usually black) and thicknesses, or natural (leaf, straw, sawdust, peat moss, gravel, etc.).

Plastic mulches have several advantages,

- Soil moisture is better conserved.
- Weeds are effectively controlled by blocking sun light.
- Soil fumigation is more effective.
- CO_2 enrichment around plant root zone.
- Permits cleaner crop produce.
- Early crops, higher yields and more income.

Floating Row Covers: A plastic film cloth known as a "Floating Row Cover" is used to shield crops from sucking pests, hoppers, beetles, and insect vectors without the need for any mechanical support. Floating coverings consist of non-woven or spun-bonded cloth with a density ranging from 10 to 50 g/m2. Single rows or multiple rows at once are covered. The main purpose of heavier covers with densities greater than 30 g/m2 is to protect against frost and freeze. Burying in the ground secures the edges. The floating covers can be used for the full growing season of leafy vegetables, which are self-pollinating crops. Under floating covers, the crops of watermelon, squash, radish, musk melon, tomato, pea, carrot, cabbage, leafy vegetables, lettuce, green beans, and cucumbers are cultivated.

Low Tunnels / Row Covers: Rows of plants in a field are sometimes covered by low tunnels that offer protection from wind, insects, and freezing temperatures. Over low (up to 1.0 m high) hoops composed of cane, bamboo strips, or steel wires, clear plastic films or nets are stretched. Films of polyethylene with venting holes (4% of surface area) and a thickness of around 50 microns are employed. PVC films are also utilized occasionally. Lately, non-woven spun-bonded porous lighter films have also been used. The low tunnel allows the plant microenvironment to be passively controlled. Low tunnels work well when combined with drip irrigation and plastic mulches. Low tunnels enable the production of melons, cucumbers, tomatoes, strawberries, capsicums, beans, summer squash, and other crops earlier and with substantially higher yields.

Cloches: A cloche is a kind of protective enclosure used in kitchen gardens, orchards, and woodlands. It is made up of a structural frame and transparent or translucent glazing material for individual plants. Cloches are eliminated once the plant has established itself well. In clear, sunny weather, the provision of natural ventilation is necessary to prevent excessively high temperatures.

Poly-house/Greenhouse: It is a large enough structure that can accommodate a person to operate within, and it is framed or inflated with a transparent or translucent cover that generates a greenhouse effect, providing at least some control over crop microclimate. In a polyhouse or greenhouse, the wintertime air temperature rise is used to grow crops, planting materials, and nurseries without the need for additional heating. The controlled ventilation of the enclosed enclosure allows for the enrichment of the air inside with a higher concentration of carbon dioxide, hence improving crop productivity. By using air conditioning, evaporative cooling, and shade, one can modify the ambient temperature and relative humidity.

Classification of greenhouse based on suitability and cost

a) Low cost or low tech greenhouse: Simple materials that can be found locally, such bamboo and stone pillars, can be used to build an inexpensive greenhouse. Materials for cladding are made from ultra violet (UV) film. Unlike traditional or high-tech greenhouses, this type of greenhouse does not come with a dedicated control unit for controlling environmental factors. On the other hand, straightforward methods are used to control the humidity and temperature. By using shade materials like nets, even the intensity of the light can be decreased. By opening the side walls in the summer, you can lower the temperature. In addition to providing protection from the elements for agricultural production, such a structure serves as a rain shelter. If not, the interior temperature rises when plastic film is applied to all sidewalls. The cold climate zones are the primary locations for this kind of greenhouse.

b) Medium-tech greenhouse: Due of the low initial expenditure, greenhouse users prefer manually or semi-automatically operated controls. Pipes made of galvanized iron (G.I.) are used to build this kind of greenhouse. With the aid of screws, the canopy cover is secured to the structure. To endure wind disturbance, the entire construction is securely fastened to the earth. To regulate the temperature, there are exhaust fans equipped with thermostats. To keep the greenhouse's interior humidity at a desirable level, misting systems and evaporative cooling pads are also installed. Maintaining a consistent climate during the cropping period is particularly challenging and time-consuming because these systems are semi-automatic, which means they need a lot of attention and maintenance. Dry and mixed climate zones are appropriate for these greenhouses.

c) Hi-tech greenhouse: In order to address some of the challenges found in medium-tech greenhouses, a high-tech greenhouse is designed with all of its components, including environmental parameter control, supported by automatic operation. High-value, low-volume vegetables can now be grown using computer-based advanced technology that fully automates temperature, humidity, and irrigation control for both local and long-distance supply.

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