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1. AGRICULTURE

Parthenocarpy: Induction and Exploitation in Cucurbits

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Abstract

Parthenocarpy, the development of fruits without fertilization, is an important trait in cucurbitaceous crops due to its potential to ensure stable fruit set under unfavorable environmental conditions. In cucurbits, parthenocarpy results in seedless or low-seed fruits, which are often preferred by consumers and beneficial for processing. The induction of parthenocarpy can be achieved through genetic, hormonal, and environmental approaches, including the application of plant growth regulators such as auxins and gibberellins, manipulation of temperature and light, and the use of parthenocarpic genotypes. Exploitation of parthenocarpy in cucurbits enhances yield, enables off-season production, reduces dependence on pollinators, and improves fruit quality under protected cultivation systems. This review highlights the mechanisms of parthenocarpy induction and its practical applications in major cucurbit crops, emphasizing its role in modern vegetable production.

Introduction

Parthenocarpy is a botanical phenomenon occurs when fruits grow from the ovary without ovule fertilization, producing seedless fruits. under horticulture, this process is crucial because it ensures that fruit sets under adverse conditions for pollination and fertilization. It can happen naturally in some plant species or be purposefully produced using hormonal or other treatments. Parthenocarpy improves fruit quality and yield stability in cucurbits, especially in locations with little pollinator activity or sheltered growing techniques (Gowda *et al.*, 2022).

Types of Parthenocarpy in Cucurbits

1. Genetic (Natural) Parthenocarpy: Because of innate hormonal characteristics, certain cucurbit cultivars spontaneously yield seedless fruits without fertilization. This stable type is employed in the development of gynoecious or seedless cultivars (Jat *et al.*, 2020).
2. Induced Parthenocarpy: Plant growth regulators (auxins, gibberellins), environmental manipulation (temperature, light), or grafting with

parthenocarpic lines can all be used to artificially encourage seedless fruit development (P. Gowda *et al.*, 2022).

Physiological and Hormonal Basis of Parthenocarpy

Hormones like auxins and gibberellins, which promote ovary development and fruit formation without fertilization, are the primary regulators of parthenocarpy in cucurbits. By altering hormone balance, cytokinins and ethylene also affect fruit growth. Parthenocarpic fruit production can also be triggered by environmental stimuli like as light, temperature, and stress. These physiological and hormonal processes are essential for the production of seedless cucurbit fruits (Jat *et al.*, 2020; P. Gowda *et al.*, 2022).

Methods of Parthenocarpy Induction

Parthenocarpy in cucurbits can be induced through hormonal, environmental, and genetic approaches to produce seedless fruits when natural fruit set is limited.

1. Application of Plant Growth Regulators (Hormonal Induction): Gibberellins (GA₃), auxins (IAA, NAA), and cytokinins are examples of exogenous hormones that can promote ovarian development and fruit formation without fertilization. Gibberellins

facilitate the growth of seedless fruit by increasing elongation and expansion, whereas auxins encourage cell division in the ovary. Cucumber, bitter melon, and pumpkin farming all make extensive use of this technique (Mishra & Tripathy, 2025).

2. **Environmental Manipulation:** Parthenocarpic fruit set can be triggered by changes in temperature, light intensity, photoperiod, or moderate stress. By changing endogenous hormone levels, high temperatures or low pollinator activity frequently promote parthenocarpy (Jat et al., 2020).
3. **Genetic and Breeding Approaches:** Stable seedless fruit production is possible through the use of parthenocarpic cultivars or hybridization with parthenocarpic lines. Additionally, grafting onto parthenocarpic rootstocks and marker-assisted selection can increase parthenocarpy in genotypes that would not otherwise be parthenocarpic (Rani et al., 2022).

Occurrence of Parthenocarpy in Major Cucurbits

- **Cucumber (*Cucumis sativus*):** Many gynoecious and parthenocarpic cultivars; widely used in protected/off-season cultivation (Jat et al., 2020; P. Gowda et al., 2022).
- **Bottle Gourd (*Lagenaria siceraria*):** Natural and hormone-induced parthenocarpy; useful under low pollination conditions (Mishra & Tripathy, 2025).
- **Pumpkin and Squash (*Cucurbita* spp.):** Rare naturally; parthenocarpy induced by hormones or hybrids; beneficial for processing and specialty markets (Rani et al., 2022).
- **Bitter Melon (*Momordica charantia*):** Some genotypes naturally parthenocarpic; can be induced by growth regulators; ensures fruit set under stress (Mishra & Tripathy, 2025).

Exploitation of Parthenocarpy in Cucurbit Production (Short Notes)

- **Protected and Off-Season Cultivation:** Seedless parthenocarpic cucurbits allow cultivation in greenhouses and off-season, ensuring consistent fruit production.
- **Pollination-Independent Fruit Set:** Parthenocarpy reduces dependence on pollinators, improving yield where pollinator activity is low.
- **Yield Stability under Stress Conditions:** Enables fruit set under high temperature, low humidity, or other stress conditions, maintaining stable yields.

Advantages of Parthenocarpy in Cucurbits

- Production of seedless fruits preferred by consumers.
- Ensures consistent yield under adverse conditions.
- Reduces reliance on pollinators.
- Facilitates off-season and protected cultivation.
- Improves fruit quality and market value.

Limitations and Challenges

- Some cultivars require hormonal treatments, increasing cost.
- Limited natural parthenocarpic genotypes in some cucurbits.
- Hormonal induction may affect fruit size or quality.
- Breeding stable parthenocarpic lines can be time-consuming.

Future Prospects and Breeding Strategies

- Development of high-yielding parthenocarpic cultivars through conventional and molecular breeding.
- Use of marker-assisted selection and gene editing to enhance parthenocarpy.
- Integration with protected cultivation for off-season production.
- Exploitation of parthenocarpy in commercial and export-oriented markets.

Conclusion

Parthenocarpy in cucurbits is a valuable trait that ensures seedless fruit production, stable yields, and better fruit quality under adverse conditions. Combined with modern breeding and protected cultivation techniques, it holds great potential for enhancing productivity and marketability of cucurbit crops.

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2. AGRICULTURE

Indian Dairy Sector: Career with a Sustainable Future

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Introduction

Dairy industry in India has witnessed a remarkable journey in last few decades. From being a net importer of dairy products in 1950s and 1960s, India has covered a lot of ground. India has transformed from a country of acute milk shortage to the world's leading milk producer. India now is world's largest producer of milk. The credit of this phenomenal success is largely attributed to "Operation Flood", a co-operative led movement started in 1970s which took in its fold millions of small holding farmers who joined the three-tier co-operative structure and increased India's milk output.

Dairying is practiced in the villages as a cottage industry meeting the house hold requirements which is scattered throughout the length and breadth of the country. India is among the world largest and fastest growing markets for milk and milk products. The average annual growth rate of milk, milk production has been approx. more than 4 percent during the past decade. Dairy processing sector plays a dynamic role in India's agro-based economy. Rapid industrialization and globalization have paved way for Indian dairies to emerge as one of the fastest growing industries of India. Indian dairy industry has made a substantial revolution as a result of white revolution for the

past few decades.

The increase in production also poses great responsibilities on the Indian dairy industry to improve the quality of the milk. Developing cutting edge and cost-effective methods are essential to produce quality products. The main aim of dairy education is to develop suitable technically trained man power to suit the needs of the industry. New research and developments programmes in milk production, quality control will generate new jobs. The dairy industry has opened up new avenues for employment and economy and now the highly specialized dairy value chain involves production, procurement, storage, processing and distribution of dairy products. Dairy Technologists mainly deal with the technological and quality assurance aspect of the processing industry and also work to develop improved methods in processing, product preservation and utilization of milk and milk products. Other areas include machinery maintenance related activities and marketing and sales of milk and milk products.

Future for Dairy Education

There is an interest and imperative for both industry and the education and training sector to discover a mutually satisfying approach. This mutual discovery requires certain things to happen. First, the industry, at

least at national level, needs to agree as to its needs and priorities for education and training of its existing and future personnel at the level of operators, technicians, scientists and managers. This has been shown to be possible at operator level in the development of competency standards in a number of countries, and at higher levels in some specific companies.

Clearly, these training and education needs would best be developed in conjunction with education and training providers so that programs developed not only connect with industry but also enjoy recognition within academic circles. The linking of training and education at various levels is an essential tool for the ongoing professional development of people within the dairy industry.

Pathways of progression are important to an individual's aspirations and can bring great benefits to companies who choose to invest in people. Given the rapid rate of change in industry, the partnership between industry and education must be ongoing if courses at all levels are to remain relevant to industry needs. Such a partnership may inform both parties on possible improvements to course content, on innovations for more tailored delivery of courses, on addressing issues of resource requirements, and on shifts in the direction of training and education in light of industry changes.

The challenge remains to harmonize industry needs with intellectual rigor in the face of the inescapable economic imperatives for industry and the constraining policies in the educational sector. This challenge will continue regardless of the structures that are devised to provide the type of education and training that the dairy industry needs. The challenge will also be satisfactorily met only if both industry and education agree that they share an interest in determining the dairy curriculum.

Changes in Dairy Industry and Impact on Education

The growing interest and expansion of organic dairy production across the world has prompted researchers and extension educators to focus their efforts on the issues most critical to the dairy industry. The results of the focus group interviews and survey questionnaire is an important first step and further inquisition

will be critical to developing relevant and effective research agendas that can provide science-based answers to questions about economic opportunities to increase profitability, methods to enhance forage production, and the utility of certain organic treatments. In addition, high-quality educational programming tailored for farmers and other stakeholders by extension educators should be developed, working closely with the industry to ensure that research findings and best practices are shared appropriately, providing farmers with the skills and knowledge they need to be successful.

Career in Dairy Sector

The manufacturing sector, the third largest sector of Indian economy, is dominated by the unorganized manufacturing and employs around 84% of the total workforce engaged in manufacturing field. Within the unorganized manufacturing, around 17% (highest) of the workforce is engaged in the unorganized food manufacturing sector (NSSO, 2005-06). Unorganized manufacturing includes all those units/factories which are not covered under the area of organized manufacturing (based on Factory Act, 1948). These units typically operate on a small scale with little or no distinction between labour and capital as factors of production.

The productivity of capital has increased at a faster rate in the organized sector than in unorganized sector. This may be due to a faster diffusion of new capital-intensive technological changes in the organized than unorganized sector. Participation of unskilled labour is more common in workforce of unorganized food processing industry. To improve its performance, there is need to develop necessary skills among the 6.3 million workers of food processing industry. The current capacity of the skill development programmes is 3.1 million. India has set a target of capacity building of 500 million people by 2022. Concerted efforts should be focused on this programme.

Dairy Technology is a challenging career which offers enormous prospects for trained professionals. There are now 1,653 registered dairy plants in the country and many Dairy equipment manufacturers which are organizing by 17,76,643 people. Greater developments

have occurred in the Dairy industry due to the impact of technological revolution. Lot of career opportunities is being created in the field of Dairy industry due to the impact of these developments. Bachelor of Technology course in Dairy Technology is one of the best courses which covers the Technological and Engineering aspects of dairy processing. After the completion of this course, one can look for lucrative career opportunities in India and abroad.

In the last two decades the spectacular growth of the dairy industry has created various demands for indigenous production of dairy equipment, increased quality standards and production of various milk products. This has also developed the dairy equipment manufacturing industry and technical consultancy organizations. Such an expansion of dairy industries and other related industries has opened up vast career opportunities for dairy engineers. Many government and private organizations are looking for professionals in the field who can perform designing, development and execution of their crucial projects.

Openings for a dairy technologist are

available in both the public and the private sector. They can find jobs in dairy farms, cooperatives, rural banks, milk product processing and manufacturing industries. Quality control departments also recruit dairy technologists. A large number of dairy technologists also start their own business such as small-scale milk plants, creamery, ice-cream units, etc or work as consultants. A consultant, however, needs years of working experience in dairy firms to be successful. Besides there are opportunities for teaching as well as Research and Development which is another growing area, crucial for the dairy industry. The graduates can also find lot of career opportunities in the quality control departments, dairy products manufacturing companies run by the government. In addition, the graduates have a huge demand in foreign countries like Australia, Denmark, New Zealand, Switzerland and Middle East countries. They can also pursue their career as Dairy technologists in foreign countries. They can also work as food inspectors, supervisors or quality controller in different foreign dairy companies.

3. AGRICULTURAL EXTENSION

Zero Budget Natural Farming: System to Reduce Farming Expenses

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Introduction

Indian agriculture need to reduce dependence on chemical fertilisers and should adopt chemical free agriculture. According to National Sample Survey Office (NSSO) data, almost 70% of agricultural households spend more than they earn and more than half of all farmers are in debt. Privatized seeds, inputs, and markets are inaccessible and expensive for peasants. Indian farmers increasingly find themselves in a vicious cycle of debt, because of the high production costs, high interest rates for credit, the volatile market prices of crops, the rising costs of fossil fuel based inputs, and private seeds. In order to achieve the Central

government's promise to double farmers income by 2022, one aspect being considered is natural farming methods such as the ZBNF which reduce farmers' dependence on loans to purchase inputs which they cannot afford. Under such conditions, 'zero budget' farming promises to end a reliance on loans and drastically cut production costs, ending the debt cycle for desperate farmers. Zero budget natural farming (ZBNF) is a method of chemical-free agriculture drawing from traditional Indian practices. Because of continuous incorporation of organic residues and replenishment of soil fertility this helps to maintain the soil health (Manish and Aksash, 2021). Zero-Budget Natural Farming

(ZBNF) is a holistic alternative to the current concept of high-cost chemical inputs based agriculture (Manida, 2021). Zero Budget Natural Farming (ZBNF) is a set of farming methods, and also a grassroots peasant movement, which has spread to various states in India.

It was originally promoted by Padma Shri recipient Subhash Palekar, who developed it as an alternative to the Green Revolution methods driven by chemical fertilizers and pesticides and intensive irrigation. He argued that the rising cost of these external inputs was a leading cause of indebtedness and suicide among farmers. Without the need to spend money on these inputs cost of production could be reduced and farming made into a “zero budget” with the help of ZBNF. Mr. Palekar is also against vermicomposting, as it introduces the most common composting worm, the European red wiggler (*Eisenia fetida*) to Indian soils. He claims these worms absorb toxic metals and poison groundwater and soil. Organic farming is being promoted under the national programme of Paramparagat Krishi Vikas Yojana (PKVY) through farmer groups. Viability of organic farming is becoming a problem due to absence of input availability and output markets. It is argued that organic farming is suitable only for horticultural crops (Guruva et al., 2019). ZBNF farmers were growing more fruits and vegetables as their main kharif crop compared to their counterparts (Niti et al., 2020)

Instead of commercial chemicals inputs, the ZBNF promotes the application of following Bio-fertilizers (Biswas, 2020)

Jivamrita/Jeevamrutha: It is a kind of bio-fertilizer which adds nutrients to the soil for plants' uptake.

Preparation: In 200 litres of water 10 kg fresh local Indian bred cow dung and 5-10 litres of aged cow urine were added. Then, 2 kg each of jaggery and pulse flour and a fist of soil from chemical less area are added in to it and mixed thoroughly. Mixture should be kept in shade for 48 hours for fermentation.

Application: Soil application of 200 litres of Jivamrita/Jeevamrutha in irrigation water for 1 acre of land twice a month or

foliar application of 10% solution.

Bijamrita/Beejamrutha: used as a treating the seed/seedling/planting material to reduce mortality rate and ensure good or vigorous crop stand on the field by checking various seed and soil borne diseases of younger seedlings.

Preparation: It is prepared same as Jivamrita/Jeevamrutha (local Indian bred cow dung and urine, lime, water and soil). Specifically, 5 litres of urine and 5 kg of dung of local Indian bred cow are put inside a container containing 20 litres of water. 50 g of lime and a fist of native soil are then added into it and thoroughly mixed.

Application: Coating and mixing the seeds by hand or leguminous seed dipping in Bijamrita/Beejamrutha solution followed by drying in shade and sowing.

Acchadana/Mulching: Protects the top soil from erosion. And also improves soil aeration and conserves soil moisture by checking evaporation water loss. Weed emergence can also be checked through mulching to some extent.

Types: Three types of mulching are used viz.

- Soil mulch (friable soil/dust coverage on top soil)
- straw mulch (dried residues of previous crops, dead materials of plants and/or animals) and
- Live mulch (symbiotic mixed or intercrops preferably with monocot and dicot such as cereal-legume cropping).

Application: Application of soil or straw mulch before sowing the seeds or sowing (cultivation) of crops to cover land spaces (live mulch).

Whapasa/Moisture: Focuses on improving water use efficiency by reducing the quantity and frequency of irrigation water applied as only a limited amount of water is needed (in form of vapour) for the crop growth. Therefore, it provides resilience from drought. Ideal situation to mix up of air and water molecules renders suitable soil aeration and reduces 90% water use which is helpful in rain fed agriculture.

Application: Irrigation during noon in

alternate furrows to make air and water molecules to remain in soil.

For Plant Protection following Bio Pesticides was Used

Bio-pesticides (*Neemastra*, *Agniastra*, *Bramhastra* etc.) were used which were made through natural or organic or bio-products. These bio pesticides are only permitted to use during the times of pest and disease outbreaks to protect the plants to reach economic injury levels.

Neemastra: Effective towards sucking insects, mealy bugs etc.

Composition: Indian breed cow urine (5lt) + Cow dung(5kg)= Neem leaves and pulp extracts (5kg) and ermented for 24hrs.

Bramhastra: Effective towards sucking pests, pod borer, fruit borer etc.

Composition: Neem leaves, Guava leaves, Papaya leaves, Custard leaves, Pomegranate leaves, White Dhatura leaves and *Lantana camara* leaves (crushed and boiled in Indian breed cow urine).

Agniastra: Effective towards Leaf roller, stem borer, pod borer, fruit borer etc.

Composition: Indian breed cow urine (5lt) + Tobacco leaf (1kg) + Garlic (500g) + Green chilli (500g) + Urine soaked neem leaves and pulp extracts (5kg).

Importance

- Reduces the farming costs by reducing dependency on chemical fertilizer, pesticides, etc., which are leading causes of indebtedness and suicide among farmers.
- Cost of production will be reduced and farming made into a "zero budget" exercise.
- Helpful in fighting against the impact of chemicals on the environment.

- ZBNF eliminates usage of chemical pesticides.
- Promotes good agronomic practices and improves soil conservation, seed diversity and quality of produce.

Conclusion

As a result of ZBNF farmers cost of production can be reduced because farmers need not to spend any amount on commercial chemicals and fertilizers. And farmers can be free from Loans and high interests this helps farmers to increase their income. Because the use of bio fertilizers and bio pesticides soil health can also be maintained.

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4. AGRICULTURAL SCIENCE

Medicinal Properties and Active Constituent of *Terminalia chebula*

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Introduction

Since the early days of civilization medicinal plants are used in treatment of different ailments. Traditional Indian system of medicines like Ayurveda, Unani and Siddha is mostly based on the use of medicinal plants. There are number of literature and ancient knowledge of these medicinal plants show their success for the treatment of different ailments. This increased use of herbal medicines in today's era is credited to the fact that these are obtained naturally and is reliable, cheap and have higher safety margins with very less reported side effects (Sharma, 2009). It is a popular traditional medicine. Its widely use in homeopathy and other traditional medicinal system because of its wide therapeutic activities associated with its biologically active chemical components present in the plants. It is not only used in India but also in other countries of Asia and Africa. The fruits of *terminalia chebula* possess various health benefits and have been used in traditional medicine. It is an important ingredient in one of the most popular Ayurvedic preparations (Triphala) together with *Terminalia chebula*, *Terminalia bellerica* & *Emblica officianallis*. constitute the preparation called Triphala. Triphala has been described in ancient Ayurvedic text as Tridoshic rasayna, a therapeutic agent with balancing the rejuvenating effects on three humors or constitutional elements in Ayurveda vata, pitta and kapha (Chattopadhyay, 2007).

Habitat: The *Terminalia chebula* tree may grow at places about 2000m from sea level and in areas with an annual rainfall 100-150cm and temperature 0.17 degrees terminalia chebula is mainly found in Nepal, Sri Lanka, Myanmar, Bangladesh and in Pakistan, Tibet, apart from Asia it is also found in countries like Egypt, Turkey and Iran. In India terminalia chebula or haritaki tree grows in deciduous forests of Himachal Pradesh, Tamil Nadu, kerala, Karnataka, Uttar Pradesh, Andhra Pradesh, West Bengal, Sikkim (Fundter *et al*, 1992).

Botanical Description

Botanical Name: Terminalia chebula

Family: Combretaceae

Genus: Terminalia

Species: Chebula

English: Black Myrobalan

India: Shilikha, haritaki, hirdo, hamija, harad, alale, katukka, manali, hirda, karadha, har, katak-k-kay, karaka, harejarad.

Major Constituents: In *Terminalia chebula*, the fundamental phytoconstituents in it are hydrolysable tannins (which may fluctuate from 32-34%) phytoconstituents present in *Terminalia chebula* steroids, amino acids, fructose, gums, fixed oils, anthraquinone, starches, glucose, sorbitol and so on the plant is genuinely wealthy in hydrolysable tannins. (Kumar, 2006), (Juang, 2004) stated that *Terminalia chebula* contain 14 components of hydrolysable tannins like gallic corrosive, chebulic corrosive, punicalagin, chebulanin, corilagin, neochebulinic, ellagic corrosive, chebulagic corrosive, 1,2,3,4,6-penta-orgalloyl- β -D-glucose, 1,6-di-o-galloyl-D-glucose and Terchebulin.

Medicinal Properties: *Terminalia chebula* possesses several medicinal properties and health benefits Some of them includes

Traditional Value	It is extensively used in Ayurveda, siddha, unani and homeopathic medicines in India. It is a top listed plant in Ayurvedic Materia medica for treatment of asthma, bleeding piles, sore throat, vomiting and gout. (Malik et al, 2012).
Urinary System	Useful in Urinary tract infection (UTI) & urinary tract disorders, consuming of 1 tea spoon of Haritaki powder with a little honey twice in a day morning & evening helped to control diabetes.
Skin Diseases	Haritaki, which is useful in the serious bacterial infection in skin and other skin ailments, prevents pus accumulation in skin diseases and functions as a

	antiaging. Oil of haritaki is extremely useful for wound healing, particularly when burning. It helps enhance the complexion of the face.
Respiratory System	Haritaki releases rhinitis, cough, voice hoarseness, hiccups and dyspnoea, wheezing, breathing trouble as it decreases congestion.
Anti-Bacterial Properties	Antibacterial properties of haritaki shows actively against gram positive and gram-negative bacteria such as salmonella typhi, staphylococcus epidermidis, pseudomonas aeruginosa, bacillus subtilis. Gallic acid and ethyl ester, these two antibacterial compounds have been isolated from ethyl extract of <i>terminalia chebula</i> fruit. <i>Terminalia chebula</i> fruit extract had strong antibacterial activity against intestinal bacteria, clostridium perfringens and E. coli. Ethanol extract is effective against salmonella typhi, staphylococcus aureus, bacillus subtilis. Ether, alcoholic and aqueous extract has potent activity against helicobacter pylori (Kannan, 2009)
Anti-Fungal Properties	Aqueous extract of the plant shows antifungal activity against a number of dermatophyte and yeasts. The alcoholic ethyle acetate extract shows the activity against <i>Aspergillus niger</i> , <i>aspergillus flavus</i> , <i>alternate</i> . 70% of methanol ethylacetate, hexane, chloroform extract shows activity against <i>fusarium oxysporum</i> , <i>phytophthora capsici</i> , <i>fusarium solani</i> etc (Dutta,1998), (Mehmood, 1999).

Wound Healing Property	Topical application of alcoholic extract of the leaves of <i>Terminalia chebula</i> caused much faster healing of rat dermal wounds.
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Conclusion

There are several evidences from literatures on the medicinal properties of *Terminalia chebula* such as Ayurveda, siddha; Unani in traditional system of medicines in India has reported the high therapeutic value. *Terminalia chebula* consists a several phytochemical or active constituents which are found to be associated with the plant extract that include mainly chebulic acid, gallic corrosive, chebulic corrosive, punicalagin, chebulanin, corilagin, neochebulinic, ellagic corrosive, chebulagic corrosive etc. All these compounds are found to be responsible for many of pharmacological activities. *Terminalia chebula* is an important herbal drug as it is used for treating many diseases.

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5. HORTICULTURE

Carbon Sequestration Potential of Vegetable Based Cropping Systems

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Abstract

Agriculture plays a dual role in climate change as both a contributor to greenhouse gas emissions and a potential sink for atmospheric carbon dioxide (CO₂). When managed sustainably, vegetable-based cropping systems, which are distinguished by high biomass turnover, intense management and a variety of cropping patterns, offer substantial prospects for carbon sequestration. Soil organic carbon (SOC) stocks are increased while soil health and productivity are improved by techniques such organic amendments, cover crops, residue recycling, decreased tillage, and diverse crop rotations. This article highlights the importance of carbon sequestration in vegetable based cropping systems in climate-smart and sustainable agriculture by reviewing the processes, influencing variables, management techniques, advantages, constraints, and future possibilities.

Keywords: Carbon sequestration, vegetable cropping systems, soil organic carbon, climate-smart agriculture, sustainable horticulture.

Introduction

One of the main causes of global climate change is rising atmospheric CO₂ concentrations. Agricultural soils are essential for mitigating climate change since they are one of the biggest terrestrial carbon reservoirs. Improved management techniques can turn vegetable-based systems into efficient carbon sinks, despite the fact that vegetable agriculture is frequently seen as carbon-intensive because to the regular tillage, irrigation, and fertilizer usage. Developing climate-resilient and sustainable horticulture techniques requires an understanding of vegetable cropping systems'

capacity to sequester carbon (Lal, 2004).

Concept of Carbon Sequestration in Agriculture

The phrase "carbon sequestration" describes the long-term storage of atmospheric carbon in biomass and soil. This mostly happens in agricultural systems through photosynthesis, which fixes carbon in plant biomass and then transfers it to the soil as organic amendments, residues, and root exudates. In addition to reducing climate change, soil organic carbon buildup enhances soil fertility, structure, and water-holding ability (Paustian *et al.*, 2016).

Characteristics of Vegetable-Based Cropping Systems

With short-duration crops, high cropping intensity, and frequent residue clearance, vegetable-based systems are usually intensive. But these systems also produce a significant amount of biomass, especially from unharvested plant parts and roots. Compared to monocropping systems, vegetable systems can greatly improve SOC sequestration when paired with organic inputs and varied rotations (Kumar *et al.*, 2018).

Mechanisms of Carbon Sequestration in Vegetable Systems

1. **Biomass Production and Root Contributions:** Both aboveground leftovers and belowground root biomass from vegetable crops add carbon to the soil. Carbon produced from roots is especially stable and makes a substantial contribution to long-term SOC pools (Lal, 2004).
2. **Soil Organic Matter Formation:** Adding green manures, compost, and agricultural leftovers encourages the development of soil organic matter (SOM). Carbon storage is improved via microbial breakdown, which converts organic inputs into stable carbon components (Paustian *et al.*, 2016).
3. **Reduced Carbon Losses:** Reduced tillage and other conservation techniques lessen soil disturbance, which lowers soil CO₂ emissions and organic carbon oxidation (Six *et al.*, 2002).

Management Practices Enhancing Carbon Sequestration

1. **Organic Amendments and Compost Use:** In vegetable fields, applying crop leftovers, compost, and farmyard manure greatly raises SOC levels. Organic inputs improve soil carbon stability by providing stable carbon and promoting microbial activity (Liang *et al.*, 2008).
2. **Cover Cropping and Green Manuring:** Grown during fallow times, cover crops like grasses and legumes increase biomass and prevent soil erosion. In vegetable systems, green manures promote nutrient cycling and carbon inputs (Poeplau and Don, 2015).

3. **Crop Rotation and Diversification:** In contrast to continuous monocropping, diversified rotations incorporating legumes, leafy vegetables, and root crops improve biomass variety and carbon inputs, resulting in increased SOC sequestration (Kumar *et al.*, 2018).
4. **Conservation Tillage Practices:** In vegetable cultivation, reduced or minimal tillage increases aggregate stability and reduces soil carbon losses, which increases the potential for carbon storage (Six *et al.*, 2002).

Carbon Sequestration Potential of Vegetable Cropping Systems

According to studies, depending on soil type, climate, and management techniques, well-managed vegetable systems may sequester 0.3–1.5 Mg C ha⁻¹ yr⁻¹. Compared to conventional systems, systems that combine organic farming methods with residue recycling have greater sequestration rates (Lal, 2004; Paustian *et al.*, 2016).

Environmental and Agronomic Benefits

- Mitigation of climate change through CO₂ reduction
- Improved soil fertility and structure
- Enhanced water-holding capacity
- Increased nutrient-use efficiency
- Improved resilience to climate variability

These co-benefits make carbon sequestration strategies attractive for sustainable vegetable production.

Constraints and Challenges

High labor costs, a lack of organic inputs, short-term yield trade-offs, and challenges in measuring SOC improvements are some of the obstacles. Furthermore, the benefits of carbon sequestration may be countered by increased nitrous oxide (N₂O) emissions due to excessive nitrogen application (Smith *et al.*, 2014).

Future Prospects and Research Needs

Future studies should concentrate on measuring long-term carbon sequestration in various vegetable systems, combining precision agriculture with carbon-smart techniques, and creating legislative incentives for vegetable

producers like carbon credits. Carbon storage may be further improved by combining protected agriculture, agroforestry, and vegetable production (Paustian *et al.*, 2016).

Conclusion

When managed sustainably, vegetable-based cropping systems have significant potential for sequestering carbon. These systems can serve as efficient carbon sinks while retaining high production through the use of organic amendments, cover crops, varied rotations, and less tillage. Achieving climate-smart and sustainable horticulture requires incorporating carbon sequestration techniques into vegetable production.

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6. AGRICULTURE

Integrated Pest Management Strategies for Vegetable Crops

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Abstract

Vegetable crops are highly vulnerable to insect pests, diseases, and weeds due to their tender growth habit, intensive cultivation, and favorable microclimates. Pest resistance, pesticide residues, environmental contamination, and health risks are all consequences of an over-reliance on chemical pesticides. By integrating cultural, mechanical, biological, and chemical strategies to control pests below economic threshold levels, Integrated Pest Management (IPM) provides a sustainable and environmentally benign strategy. In order to ensure agricultural production, environmental safety, and economic viability, IPM places a strong emphasis on prevention, monitoring, and prudent pesticide usage. The ideas, elements, uses, advantages, and difficulties of integrated pest management (IPM) techniques in vegetable crops are reviewed in this article, emphasizing their significance in sustainable gardening.

Keywords: Integrated Pest Management, vegetable crops, biological control, sustainable agriculture, pest control.

Introduction

The production of vegetables is vital for

both agricultural revenue and nutritional security, but it is severely limited by diseases, nematodes, and insect pests. Vegetable crops

frequently undergo repeated pesticide treatments due to frequent harvests and high aesthetic standards, which causes residue issues and insect resistance. The need for better pest management techniques has grown as people become more conscious about environmental preservation and food safety. A scientifically validated method that strikes a balance between pest control and ecological sustainability is integrated pest management, or IPM (Kogan, 1998; Peshin *et al.*, 2009).

Concept and Principles of Integrated Pest Management

A comprehensive strategy based on ecological principles, integrated pest management combines several effective pest control techniques. Among the fundamental tenets of IPM are:

- Prevention and avoidance of pest outbreaks
- Regular monitoring and pest surveillance
- Use of economic threshold levels (ETL)
- Integration of multiple control tactics
- Minimal and need-based use of pesticides

IPM aims to keep pest populations below levels that are economically detrimental rather than completely eradicating them (Dent, 2000).

Major Pests affecting Vegetable Crops

Vegetable crops are attacked by a wide range of pests, including:

- Insect pests: Aphids, whiteflies, thrips, fruit flies, caterpillars, beetles
- Diseases: Fungal (powdery mildew, downy mildew), bacterial (wilt), viral (mosaic viruses)
- Nematodes: Root-knot nematodes (*Meloidogyne* spp.)

These pests cause direct yield loss and indirectly transmit plant pathogens (Nene and Thapliyal, 1993).

Components of IPM in Vegetable Crops

- Cultural Control: The goal of cultural practices is to make it difficult for

pests to proliferate. Crop rotation, intercropping, timely planting, resistant variety utilization, sanitation, and balanced fertilizing are a few of them. While intercropping lessens pest colonization, crop rotation aids in disrupting insect life cycles (Altieri *et al.*, 2005).

- Mechanical and Physical Control: Mechanical techniques use manual picking, traps, barriers, and nets to directly remove or destroy pests. Vegetable crops are often monitored and controlled using sticky traps, pheromone traps, light traps, and insect-proof netting (Dent, 2000).
- Biological Control: Using natural enemies like diseases, parasitoids, and predators is known as biological control. *Trichogramma* species, *Chrysoperla carnea*, ladybird beetles, *Beauveria bassiana*, and *Bacillus thuringiensis* are examples of common biological agents. These substances reduce insect populations without endangering the ecosystem (Van Lenteren, 2012).
- Botanical and Biopesticides: Eco-friendly substitutes for synthetic chemicals include biopesticides like *Bacillus thuringiensis* and nuclear polyhedrosis virus (NPV) and botanical pesticides like neem (*Azadirachta indica*) products. They are safe for beneficial organisms, biodegradable, and target-specific (Isman, 2006).
- Chemical Control (Judicious Use): In IPM systems, chemical pesticides are utilized as a last option. It is desirable to use selective pesticides with low toxicity, brief persistence, and little effect on species that are not the intended target. In order to prevent needless pesticide use, application is based on economic threshold levels (Kogan, 1998).

Pest Monitoring and Surveillance

An essential part of IPM is routine pest monitoring. It includes weather-based forecasting algorithms, trap counts, and field

scouting. Monitoring lowers crop losses and input costs by assisting in the early discovery of pests and the prompt application of control measures (Peshin et al., 2009).

IPM in Major Vegetable Crops

Certain crops, including tomatoes, brinjal, cabbage, cauliflower, chillies, and cucurbits, have successfully adopted IPM techniques. For instance, fruit borers in tomatoes and brinjal are successfully managed using pheromone traps in conjunction with biological control, whereas pest prevalence in cole crops is decreased with net homes and biocontrol agents (Singh et al., 2016).

Benefits of IPM in Vegetable Production

Adoption of IPM provides multiple benefits:

- Reduced pesticide use and residues
- Lower risk of pest resistance
- Conservation of natural enemies
- Improved environmental and human health
- Higher net returns to farmers.

IPM contributes significantly to sustainable and safe vegetable production systems (Pretty & Bharucha, 2015).

Constraints and Challenges in IPM Adoption

Despite its advantages, IPM adoption faces challenges such as:

- Lack of farmer awareness and training
- Limited availability of biocontrol agents
- Slow action of biological methods
- Initial complexity in implementation

Strengthening extension services and farmer education is essential for wider adoption.

Future Prospects of IPM

Digital solutions including pest forecasting models, mobile advisory services, remote sensing, and AI-based pest detection will be progressively included into future IPM plans.

Under changing climatic scenarios, climate-smart IPM techniques will be crucial for controlling new pests (Pretty and Bharucha, 2015).

Conclusion

Digital solutions including pest forecasting models, mobile advisory services, remote sensing, and AI-based pest detection will be progressively included into future IPM plans. In order to manage new pests under changing climate scenarios, sustainable vegetable production, and long-term agricultural resilience, climate-smart IPM techniques will be crucial.

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7. AGRICULTURE

Tomato Pomace as a Source of Nutraceuticals - An

Overview

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Introduction

One of the major drawbacks of food manufacturing industries was food waste which contains high value components like polysaccharides, flavor compounds, proteins, phytochemicals which acts as functional ingredient in both pharmacologically and nutritionally. To minimize the cost of waste disposal several techniques for recovery were successfully applied in terms of tomato processing. Lycopene is a fat soluble compound (carotenoids) present in different foods for giving color with a molecular structure of $C_{40}H_{56}$. Important source of lycopene was tomatoes available at cheap cost and it has a huge demand in the market due to its carotenoids content. The pigment which contains conjugate double bond is responsible for absorbing light during process of photosynthesis. The factor which effects the lycopene content present in tomatoes are the water content of 50-75%. High amount of lycopene content was in cherry tomatoes. The cis-isomer of lycopene was absorbed in greater amount compare to trans-lycopene because of solubility in bile acids for making it bioavailable. Lycopene is an unsaturated acyclic carotenoid with 11 linear conjugated and two non-conjugated double bonds, its not a precursor of vitamin A. These are the important physico-chemical properties which are mostly seen when used in application of nutraceuticals.

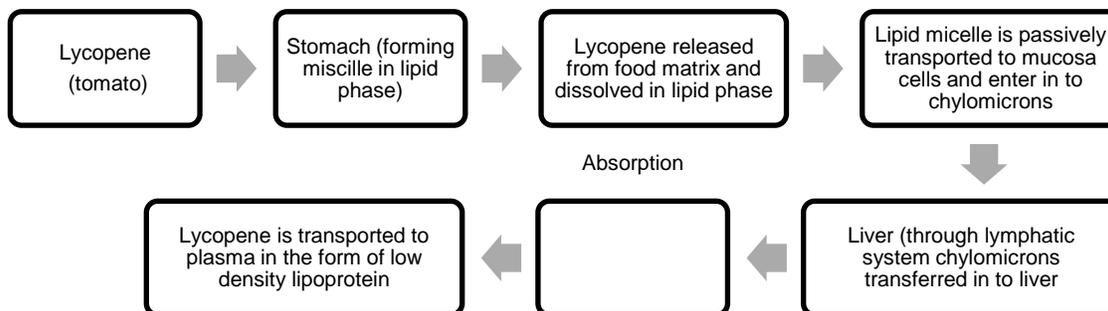
Extraction of Lycopene from Food

The beneficial biological effects of lycopene it is used as nutraceuticals, functional food and supplements. Instead of usual extraction techniques new technologies were developed for improving the recovery rate from tomato peel. The extraction process of lycopene content may increase the bioavailability in human body. By using thermal processing also we can go for extraction of lycopene but it is done by controlled process it affects the sensory properties and health benefits of final products. The extraction methods of lycopene

were broadly divided in to 2 types like green techniques and organic solvent extraction. The green house technique was used due to organic solvents are toxic to environment, the toxic traces in the final product may make the product unfit for consumption. In the organic solvent extraction the commonly used methods were soxhlet extraction, microwave assisted extraction, solvent extraction, enzyme assisted extraction, high hydrostatic pressure assisted extraction and ultrasound-assisted extraction and in green house technique most commonly used one is supercritical fluid extraction. After extraction, concentration process is carried out to create more stable extract in terms of physical, chemical and microbial characteristics. The concentration process eliminates the solvent from the sample, lowering its humidity and extending its shelf life while lowering transportation expenses. Hot air, spray dryer, rotating evaporator, lyophilization and far-infrared radiation are the most prevalent procedures for concentrations. The main disadvantage of some methods, such as hot-air and spray-drying because it causes degradation such color darkening, nutritional value loss, flavor changes. The rotating evaporator, lyophilization and far-infrared radiation are the best options. The concentration methods are also use to prepare the sample for identification analysis. Before making the product available on the market, identification analysis determines if they obtained extract meets the quality requirement using lycopene measurement and purity determination. The most common method was high-performance liquid chromatography which was found in 76% of the retrieved items. Nuclear magnetic resonance came in second with 9%, followed by ultraviolet-visible and infrared spectroscopy both with 7%. The authors observed remaining 1% in other spectrophotometric techniques. With increased interest in the nutraceuticals advantages of these potential carotenoids, both food extraction and chemical synthesis have shown symptoms of slowing. More study has been

done in this area in order to find other pathways, such as metabolic engineering.

Ingestion and Absorption:



Therapeutic uses of Lycopene

Tomatoes and tomato-based products are good providers of a number of phytochemicals that may have health advantages. Tomatoes are high in vitamin C, vitamin A, potassium and folate, among other nutrients. Lycopene was found to be the most powerful antioxidant. Carotenoids in mixtures were more efficient than single substances. When lycopene or lutein was present, the synergistic effect was strongest. Lycopene acts as a scavenger of singlet oxygen (1O_2) and peroxy radicals ($LOO\cdot$) in the body. In energy transfer reactions, lycopene's highly conjugated double bonds play the most crucial role. Diabetics have a high level of free radicals, which can cause difficulties, however antioxidants like lycopene can help to minimize complications and function as an anti-diabetic. Lycopene has inherent ability to reduce free radicals which is beneficial in several diseased conditions in old age. The impairment in memory in old age can be minimized by regular use of lycopene containing product. The treatment of lycopene using 3-nitropropionic acid-induced rats has significantly improved the memory and restored glutathione system functioning. Increased plasma lycopene levels have been linked to a lower risk of cardiovascular disease and breast cancer.

Nano carriers are being Used to Improve Lycopene solubility, Stability, and Bioavailability

Although lycopene has numerous biological properties, its use presents some challenges due to characteristics such as high

lipophilicity, insolubility in aqueous solvents, and stability and degradation issues. Solutions, such as its association with nanotechnology, are being sought to avoid these difficulties. Nanotechnology has been extensively researched as a means of increasing lycopene accessibility, bioavailability, and absorption because it can protect the molecule, improve properties such as solubility and bioavailability, and avoid toxicity issues. By use of nanoparticles it was come to know that there was low degradation of lycopene.

Anti-Oxidant Activity of Tomato Waste

Tremendous reactivity of lycopene long polyene chain with free radicals, lycopene is an excellent antioxidant, allowing singlet oxygen to be eliminated and reactive oxygen species to be reduced (ROS). Reduced ROS accumulation and oxidative stress, inhibition of inflammatory pathways (TNF-, IL-6, and IL-1), NF-kB and apoptotic (caspase and Bcl-2), and activation of the nuclear factor E2-related factor 2 (NFE2L2)-antioxidant response element (ARE), increasing antioxidant enzymes levels like superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (bMECs). There was an increase in heme oxidase (HO-1) mRNA expression in cardiac myo-fibroblast cells (H9c2), which was likewise induced by oxidative injury. Lycopene lowered levels of kinases over expressed in oxidative stress (p-ERK1/2, p-JNK, and p-p38), stress proteins (hsp70 and hsp90), and an indication of ROS-induced DNA damage in THP-1 cells exposed to H_2O_2 (8-OHdG). IKK activation/phosphorylation, I κ B implicated in NF-kB inactivation, and NADPH oxidase-4 expression

linked to ROS generation were also suppressed. Other antioxidant mechanisms involving the NFE2L2 pathway include a decrease in interferon-gamma and IL-10 levels in C57BL/6 mice lungs after cigarette smoke exposure, and a reduction in malondialdehyde (MDA), myeloperoxidase (MPO), and caspase-3 in lungs and kidney tissues in Sprague-Dawley rats with thermal trauma (oxidative injury).

Utilization of Tomato Pomace Waste as by-Products

The principal component of the peel portion of tomato pomace is cutin, which is non-toxic, biodegradable, and water-proof. Tomato pomace is also a source of natural pectin (8 percent wt. on dry basis), a thickening agent utilized in the food sector, according to researchers. Due to its health-beneficial features, researchers studied the tomato peel composition and established its potential usage as a source of carotenoids, natural colors. Tomato pomace is the leftover cuticle (or peel), seeds, and small amounts of pulp from the processing of tomatoes. It's frequently used in animal feed as a source of dietary fibre, B vitamins, lycopene, and, to a lesser extent, vitamin A.

Conclusion

Many researchers have found that consuming lycopene-rich foods can help avoid degenerative illnesses in humans. Lycopene's interaction with other active chemicals is critical to its optimal function in human health. In the gastrointestinal tract, the isomer cis is more soluble, making it easier to absorb. On the other hand, this isn't a naturally occurring isomer; instead, it's usually the consequence of an isomerization. External variables, primarily high temperatures, trigger isomerization processes, which can degrade the final product, impacting not just its sensory quality but also its health advantages. Solvent extraction and supercritical fluid extraction were found to be the most popular extraction procedures in

recent years. Centrifugation and evaporation, primarily using a vacuum rotary evaporator, were the most often utilized concentration methods. The most popular analytical procedures used by researchers were HPLC and UV-vis spectrophotometer. Another aspect to consider is that lycopene's insolubility in aqueous solvents, stability, and degradation make it difficult to employ as a nutraceuticals. Nonetheless, due to the lack of conclusive results on the role of lycopene in human health, more research into clinical aspects of lycopene, its mechanism of action in diseases, bioavailability, bioaccessibility, recommended intake, interaction with other compounds, and metabolites activities is required.

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