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Contents

1. ENTOMOLOGY

Bioplastics from Food Waste: A Path to Sustainable Plastics and Waste Reduction

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Abstract

The growing concern over plastic pollution has accelerated the search for sustainable alternatives, and bioplastics have emerged as a promising solution. Bioplastics, derived from renewable resources, offer an environmentally friendly alternative to conventional plastics made from petrochemicals. Food waste, a major environmental issue globally, can serve as a valuable feedstock for producing bioplastics. This article explores the preparation of bioplastics from food waste, focusing on the process, benefits, challenges, and potential applications. Utilizing food waste not only reduces environmental impact but also adds value to materials that would otherwise contribute to landfill accumulation.

Keywords

Bioplastics, Food Waste, Sustainable Materials, Green Chemistry, Polymers, Plastic Pollution, Renewable Resources, Environmental Sustainability.

Introduction

The global plastic pollution crisis has spurred significant interest in finding biodegradable and sustainable alternatives to conventional plastics. Among these, bioplastics, made from natural and renewable sources, have shown considerable potential. Food waste, which constitutes a significant portion of global waste and contains complex organic materials, can be utilized as an excellent raw material for bioplastic production. Food waste includes discarded items like fruit and vegetable peels, rice husks, and potato starch, all of which are rich in starch and cellulose – key components in bioplastic manufacturing.

Materials Used for Bioplastic

Production

Several types of food waste can be processed into bioplastics. These include:

- **Starch-Based Materials:** Starch, present in many food waste products (e.g., potato peels, corn, and rice), is an ideal raw material for bioplastic production due to its ability to form a gel-like structure when heated with water.
- **Cellulose:** Found abundantly in fruit and vegetable peels, cellulose is a polymer that can be extracted and used to produce bioplastics. It provides strength and rigidity to the material.
- **Proteins and Lipids:** Some food waste, such as from soybeans, peanuts, or corn, contains proteins and lipids, which can also be used in the synthesis of biodegradable plastics.

Methodology

The process for preparing bioplastics from food waste involves several steps:

1. **Collection of Food Waste:** Food waste materials, such as fruit peels, vegetable scraps, and starch-rich waste (e.g., potato skins), are collected from households, markets, or food processing industries.
2. **Pre-Treatment and Extraction:** The waste materials are washed, dried, and sometimes ground to facilitate the extraction of starch or cellulose. In some cases, enzymes are used to break down complex carbohydrates into simpler sugars.
3. **Polymerization:** The extracted starch or cellulose is mixed with a plasticizer (e.g., glycerol or sorbitol) and water to form a homogenous mixture. The mixture is then heated to allow the polymers to interact and form a plastic-like material.
4. **Molding and Drying:** The plastic material

is poured into molds or spread into thin sheets, where it is dried to remove excess moisture, resulting in a flexible or rigid bioplastic, depending on the formulation.
5. **Testing and Characterization:** The produced bioplastics are subjected to tests for their mechanical properties, biodegradability, and thermal stability to ensure they meet industry standards.

Results and Discussion

The production of bioplastics from food waste has shown promising results in terms of both sustainability and functionality. The key findings include:

1. **Biodegradability:** Unlike conventional plastics, bioplastics made from food waste are biodegradable and can decompose naturally, reducing their environmental impact.
2. **Strength and Durability:** The strength of the bioplastics can be enhanced by adjusting the ratio of starch or cellulose and incorporating plasticizers. Food waste-derived plastics can achieve tensile strength comparable to some petroleum-based plastics, making them suitable for various applications.
3. **Environmental Impact:** Using food waste as a raw material significantly reduces waste sent to landfills, helping to mitigate environmental pollution. Additionally, food waste-based bioplastics have a smaller carbon footprint compared to traditional plastic production, as they utilize renewable resources and require less energy to produce.
4. **Cost-Effectiveness:** The cost of producing bioplastics from food waste is often lower than from other raw materials such as corn or sugarcane, making it an economically viable option for sustainable plastic production.

However, challenges exist, including scalability, the variability of raw material quality, and the need for additional research to optimize production processes and properties.

Applications of Food Waste Bioplastics:

Bioplastics derived from food waste can be used in a wide range of applications, such as:

1. **Packaging Materials:** Biodegradable packaging made from food waste bioplastics can replace single-use plastic packaging, reducing plastic pollution.
2. **Agricultural Films:** Bioplastics can be used as mulch films or seedling trays, offering a more sustainable alternative to conventional plastics in agriculture.
3. **Disposable Cutlery and Tableware:** Bioplastics made from food waste can be molded into cutlery, plates, and cups, providing a sustainable alternative to plastic disposables.
4. **Biomedical Applications:** Food waste bioplastics can also be used for making wound dressings, drug delivery systems, and other medical products due to their biocompatibility and biodegradability.

Conclusion

The preparation of bioplastics from food waste represents a promising and sustainable alternative to conventional plastics. By utilizing food waste materials, we can reduce the environmental burden caused by plastic pollution while creating valuable biodegradable products. This approach not only tackles the issue of food waste but also offers an innovative solution for producing eco-friendly plastics with a wide range of applications. Continued research and technological advancements in bioplastic production will be key to optimizing the process and making it scalable for global use.

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2. AGRICULTURE

Impact of Long-Term Inorganic Nutrient Management on Soil Organic Carbon

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Introduction

Soil organic carbon – A key to the soil health

Soil health, according to the Intergovernmental Technical Panel on Soils[1] is "*the ability of the soil to sustain the productivity, diversity, and environmental services of terrestrial ecosystems*". Soil organic matter (SOM) and soil organic carbon (SOC) are crucial for soil quality, as they are the significant determinants of soil health, influencing soil physical, chemical, and biological properties that govern soil fertility and productivity. The term SOM usually refers to the total organic material in the soil, consisting of both living and dead materials, whereas SOC specifically refers to the carbon content within that organic material. Since carbon is a fundamental component of SOM, these two terms are closely related, however the SOC is a more focused metric often used in studies of soil health and climate change. The SOC is one part of the much larger global carbon cycle, and to one-meter soil depth, the SOC pool stores 1500 Petagram carbon[2], that is 3.4 times the size of the atmospheric pool and 4 times the biotic pool.

Green revolution & organic farming: Impacts on SOM / SOC

The green revolution, which began in the mid-20th century, marked a significant transformation in global agriculture[3]. The introduction of high-yielding crop varieties, extensive irrigation, chemical fertilizers, and pesticides, significantly increased food production. Worldwide, fertilizer consumption increased dramatically as countries sought to improve agricultural productivity to feed growing populations. However, concerns have emerged about its long-term sustainability, especially its impact on soil health. Intensive farming practices are often linked to SOM & SOC depletion and are a subject of significant interest and debate. Critics of synthetic fertilizers, particularly proponents of organic farming, argue that chemical fertilizers negatively impact soil quality[4,5]. Potentially, fertilizer application can affect SOM & SOC dynamics via two mechanisms[6], (i) it may increase the SOC by promoting plant & root biomass, and (ii) it may accelerate the SOC loss via increasing microbial activities. In context to the first mechanism, the purpose of the seminar is to discuss the research findings of several long-term fertilizer experiments in India and worldwide.

Long-Term Fertilizer Experiments & Research Findings

Long-term fertilizer experiments (LTFEs) are research studies conducted over extended periods, often decades, to assess the sustained impact of fertilizer and nutrient management practices on soil health, crop productivity, and environmental quality. Such experiments were initiated in various parts of the world, including India, which provided critical insights into sustainable agricultural management. The LTFEs have been instrumental in understanding the effects of nutrient management practices on SOC dynamics.

Research findings of LTFEs in India

Just after the beginning of the green revolution, the Indian Council of Agricultural Research initiated the All India Coordinated Research Project on LTFE in 1970. These experiments spread across 11 agroclimatic zones of India, covering 7 major cropping systems under 4 dominant soil types. It has been well established that a balanced nutrient supply is vital for proper maintenance and improvement of SOC. **Thakur *et al.* (2011)[7]** observed that the SOC content of Vertisols with an initial value of 5.7 g/kg had increased significantly after 36 years of continuous application of 100-150% NPK under intensive soybean-wheat cropping systems and attained a value of 7.1-8.5 g/kg. For the same LTFE, after 44 years, **Tiwari *et al.* (2024)[8]** also reported increased SOC and soil microbial biomass carbon (SMBC) for plots receiving 100-150% NPK fertilizer. Also**, Bahera *et al.* (2007)[9]** observed no significant decline in SOC of plots receiving NPK fertilizers under a wheat-soybean cropping system for 5 years compared to unfertilized plots. For the same cropping system in the sub-temperate agro-ecosystem of the Indian Himalayas, **Bhattacharyya *et al.* (2008)[10]** revealed that 30 years of the sole application of NPK led to a significant increase in both SOC and SMBC contents. After 32 years of LTFE under a maize-wheat cropping system, **Rasool *et al.* (2008)[11]** reported 21% higher SOC in 0-60 cm profile of sandy loam soil of NPK treated plots than of control plots. However, **Chakraborty *et al.* (2011)[12]** reported that mineral fertilizers resulted in statistically comparable SOC levels in the jute-rice-wheat system, although higher fertilizer dose was associated with increased SOC value. In contrast, the authors observed significant variations in MBC content attributable to mineral fertilizer application. **Tripathi *et al.* (2014)[13]** emphasized that the total organic carbon (TOC) content of plots after 42 years of application of NPK fertilizers in a tropical rice-rice system was statistically equivalent to FYM-treated plots. In the maize-wheat system, **Brar *et al.* (2015)[14]** reported that continuous use of inorganic fertilizers for 36 years increased the SOC to 3.34-3.71 g/kg compared to the unfertilized control (3.08 g/kg). The carbon sequestration rate also increased under inorganic fertilization for 36 years**[14]**. For the groundnut-wheat cropping system in calcareous loam soil, **Deshraj *et al.* (2015)[15]** observed ~35% increase in the SOC with the use of inorganic fertilizers for 12 years compared to their initial SOC values. **Chaudhary *et al.* (2017)[16]** demonstrated that the continuous application of NPK fertilizers alone to rice-wheat cropping system for 15 years improved the SOC (i.e., 4.19 g/kg from its initial value of 2.42 g/kg) and its labile fractions in soils under intensive rice-wheat system. The authors also found a better carbon management index, CMI (59%) for the surface soil under NPK treatment, implying that the SOC status has improved. After 44 years of wheat based cropping in Inceptisol, **Ghosh *et al.* (2018)[17]** reported nearly two-fold increase in SOC and SOC stock with 100% and 150% NPK treatments than control plots. The authors also noticed a considerable rise in the SOC fractions, MBC, CMI, OC accumulation, and CS rate after 44 years of mineral fertilization**[17]**. **Das *et al.* (2019)[18]** reported 12% increase in the TOC in colloidal organo-mineral fraction extracted from different soils after 31 years of fertilization. **Srinivasarao *et al.* (2020)[19]** examined a 16-years LTFE with mono-cropping rainfed groundnut to quantify the influence of fertilization on SOC in rainfed Vertisols, and authors noticed no significant decline in SOC owing to 100% NPK compared to the initial status. **Singh *et al.* (2021)[20]** reviewed the effect of various LTFEs on depletion/sequestration of carbon and concluded that the increase in amount of applied nutrients (NPK) from 50% to 150% resulted in an increase in carbon sequestration, which is ascribed to increase in total biomass or primary productivity of crops. **Rathod *et al.* (2024)[21]** demonstrated that the NPK fertilization for 32 years in Vertisol under a sorghum-wheat cropping sequence increased SOC, TOC, and carbon sequestration parameters compared to unfertilized control plots.

Research findings of LTFEs worldwide

Singh (2018)[6] reviewed the findings of various LTFEs from all over the world and stated that adequate and balanced use of mineral fertilizers increased SOC as compared to plots receiving no fertilizers. The Broadbalk experiment at Rothamsted[22] is one of the longest-running agricultural experiments in the world, initiated in 1843 in UK. The results of this experiment on changes in the SOC status after 175 years reveal that the plots receiving only inorganic fertilizers have exhibited relatively stable SOC levels[22]. Gao *et al.* (2015)[23] assessed the 33-years LTFE on the fluvo-aquic soil of North China in a wheat-maize rotation and found that application of inorganic fertilizer enhanced the SOC content by 28-47% over its initial SOC value. Likely, Zhao *et al.* (2015)[24] assessed a 12-years experiment under a rice-wheat system to study the changes in the SOC and soil microbes due to long-term fertilization and concluded that the long-term fertilization increased the SOC by 13-23% in plough soil layer. Results further showed that fertilizers stimulated the population of soil microbes[23]. Ashraf *et al.* (2020)[25] similarly observed no decline in the SOC content due to application of inorganic fertilizers in rice-wheat system for 37 years.

Conclusion

Soil organic carbon (SOC) is a key determinant of soil health, influencing soil fertility, productivity, and ecosystem services. Long-term fertilizer experiments (LTFEs) conducted both in India and globally have demonstrated that balanced and adequate application of inorganic fertilizers can significantly enhance SOC levels, total organic carbon (TOC), and related carbon management parameters across various agroecosystems. Indian studies reveal that the application of 100-150% NPK fertilizers in diverse cropping systems over decades consistently increased SOC content, microbial biomass carbon (MBC), and carbon sequestration rates. Similarly, global research confirms the positive effects of mineral fertilizers on SOC stabilization and enhancement. Notable findings include the All India Coordinated Research Project on LTFE in India, Broadbalk experiment in the UK and trials in China, which show sustained or improved SOC levels with long-term fertilization. These improvements are attributed to enhanced plant biomass production, soil microbial activity, and carbon sequestration. However, some studies indicate limited SOC gains in specific conditions, emphasizing the need for customised nutrient management strategies. Overall, the evidence underscores that balanced inorganic fertilization is crucial for maintaining and improving SOC stocks, thereby promoting sustainable soil health and long-term agricultural productivity.

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3. SOIL SCIENCE

Biofertilizers and Its Mechanism of Action in Soil for Crop Nutrition

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Introduction

Biofertilizer is the microbial inoculants that contain the culture of dormant or live cells of the effective strains of N-fixing, P-solubilizing or mobilizing, and K-solubilizing. Microorganisms at their cellular level which is often applied to seeds, soils, or compost material to accelerate the microbial activities by such organisms through their multiplication and enhance the nutrient's availability, which can be easily accessible by the plants. The biological activity of microbial inoculants helps in mobilizing the availability of nutrients and recovery of nutrients, thereby improving the soil quality in general.

Classification of Biofertilizers

Biofertilizers can classify into various types such as Nitrogen Fixing Biofertilizer, Phosphate Biofertilizers, Biofertilizers for Micro-nutrients, and Plant Growth Promoting Rhizobacteria, etc. Nitrogen-Fixing biofertilizers raise the nitrogen level of soil by fixing atmospheric nitrogen and making it available to the plants. Examples: Azotobacter, Nostoc, Rhizobium, Azospirillum. Phosphate Biofertilizers include phosphorous solubilizing biofertilizers (PSB) and phosphorus mobilizing biofertilizers (PMB). PSB solubilizes the insoluble phosphate from organic and inorganic phosphate sources. Examples include species of Bacillus, Pseudomonas, Penicillium, Aspergillus, etc. PMB transfer the phosphorus from the soil to the root cortex. Examples: Arbuscular Mycorrhiza (AM fungi). Biofertilizers for micro-nutrients include silicate and zinc solubilizers bacteria. These bacteria degrade silicates and aluminum silicates in soil. Example: *Bacillus* sp. Plant Growth Promoting Rhizobacteria (PGPR) are the bacteria present in the rhizospheric region. They promote plant growth by acting as Bioprotectants, Biostimulants, and by improving nutrient availability.

Mechanism of Action

Mechanism of action refers to the biological and chemical process by which microorganisms contained in biofertilizers exert their effects applied to the plant's rhizosphere. The rhizosphere is a thin layer of soil surrounding the roots characterized by high levels of biochemical activities and comprised of plant, bacteria, fungi, and soil constituents. Moreover to these zones were found to contain microbial cells of more than 1010 per gram of root and over 30,000 different bacterial species. Interestingly, these interactions between plant-root and microbial populations have characterized as symbiosis. As the microorganism access the unavailable nutrients elements into available form through decomposition, the later benefit from root exudates such as carbohydrate, proteins, sugars, vitamins, mucilage, amino acids, and organic acids, which modify biochemical properties of the rhizosphere through the application of these root exudates by acting as a messenger between the microbes and the plants. Biofertilizers mediates plant growth performance by direct and indirect mechanisms.

Direct Mechanisms

Direct mechanisms influence the plant growth activity directly. It includes nitrogen fixation, phytohormones production, phosphate solubilization, etc.

1. **Biological Nitrogen Fixation (BNF):** BNF converts atmospheric N_2 to plant-utilizable forms by nitrogen-fixing microbes employing a complicated enzyme system known as nitrogenase to convert nitrogen to ammonia. Nitrogen-fixing organisms are broadly classified as (a) symbiotic N_2 fixing bacteria, which form a symbiosis with leguminous plants (e.g. rhizobia) and non-leguminous trees (e.g. Frankia), and (b) non-symbiotic (free-living, associative, and endophytes) nitrogen-fixing forms, which include cyanobacteria (*Anabaena, Nostoc*), *Azospirillum, Azotobacter, Gluconoacetobacter diazotrophicus,* and *Azocarus,* etc.
2. **Plant Hormones Production:** The production of plant hormones is the key feature of microbes which is used as a biofertilizer. Beneficial microbes produce plant hormones such as IAA (indole-3-acetic acid), gibberellins (GA), etc. IAA mainly regulates plant cell division, cell differentiation, increases root length, etc. GA triggers root shoot elongation, seed germination, flowering and fruiting in the plant. The movement and concentration of GA are essential for the different developmental stages of plants and useful for crop.
3. **Nutrient Solubilizers:** Phosphate-solubilizing microorganisms (PSM) have phosphate-solubilizing activity that can offer accessible fertilizers. PSBs are potential biofertilizers among the different PSMs, due to rapid adaptation in the rhizosphere and organic acid production. The production of organic acids is the primary mechanism of inorganic phosphate solubilization. The beneficial effects of PSB on plant and soil

health and observed that PSB produces low molecular weight organic acids such as oxalic acid, fumaric acid, formic acid, α-ketoglutaric acid, lactic acid, maleic acid, propanedioic acid, acetic acid, and acrylic acid. Bacterial genera like *Pseudomonas, Burkholderia, Azotobacter, Enterobacter, Bacillus, Rhizobium, Beijerinckia, Serratia, Microbacterium, Flavobacterium, and Erwinia* are reported as the most significant phosphate-solubilizing bacteria.

Potassium solubilizing bacteria (KSB) have been shown to solubilize K-bearing minerals and convert insoluble K to soluble forms that plants may absorb. *Acidothiobacillus ferrooxidans, Paenibacillus* spp., *Bacillus licheniformis, and Burkholderia cenocepacia*, *Klebsiella variicola*, *Enterobacter cloacae, Bacillus cereus* and *Bacillus circulans* releases organic acids which can solubilize K minerals (e.g., biotite, feldspar, illite, muscovite, orthoclase, and mica).

Plants may take up zinc as a divalent cation, but only a small percentage of total zinc is soluble in soil. The remaining zinc is found as insoluble compounds and minerals. Zinc deficiency arises as a result of zinc shortage in the soil, and it is one of the most common micronutrient deficiencies. *Pseudomonas aeruginosa* HMR1, a PGPR which showed zinc solubilizing activity. *Rhizobium* strains, *Bacillus aryabhattai* , *Bacillus* sp. and *Azospirillum* can release organic acid and solubilize zinc in the rhizospheric region.

4. **Siderophore Production:** Siderophores are low-molecular-weight iron-binding protein molecules that aid in the chelation of ferric iron (Fe3+) in the environment. Siderophores produced by microorganisms has been widely recognized as bio-remediation, bio-controls, bio-sensors, and as a chelation agent. It also takes part in weathering of soil minerals. Microbial siderophores deliver Fe to plants when Fe is scarce, allowing them to grow faster. When there is a lack of iron, these molecules work as solubilizers for iron from minerals or organic substances. In general, siderophores form 1:1 complexes with Fe^{3+}, which are subsequently taken up by the cell membrane of bacteria, where the Fe^{3+} is reduced to Fe^{2+} and released into the cell.

Indirect Mechanisms

The indirect mechanism doesn't influence plant growth directly, but it protects the plant from the deleterious effects of plant pathogens. The production of HCN, antibiotic, siderophore, lytic enzymes (such as chitinases, cellulases, 1,3-glucanases, proteases, and lipases), etc., are the indirect-mechanism of biofertilizers that lyse the cell walls of many pathogenic fungi.

1. **HCN and Ammonia Production:** HCN and ammonia production are considered to be indirect plant growth promoters. HCN is a volatile substance that has antifungal properties. Ammonia production can assist the host plant meet its nitrogen requirements while also reducing pathogen invasion. HCN is also utilized in the chelation of metal ions and is indirectly implicated in making phosphate available. Few PGPR produce and synthesize HCN, and acts as biological fertilizers or biocontrol agents to boost crop yields.
2. **b) Chitinase Production:** The production of chitinase by microbes has been considered as one of the strategies for controlling plant pathogens. Chitinase induces the breakdown of the cell wall, which affects the structure's integrity and hence inhibits pathogen development. Chitinase attacks chitin (1,4-*N*-acetyl-glucosamine), which is an essential component of the fungal cell wall. Chitinolytic activities found in *B. thuringiensis, B. licheniformis, B. circulans, B. cereus, and B. subtilis.*

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4. HORTICULTURE: POST HARVEST TECHNOLOGY

Non-Destructive Techniques in Quality Evaluation of Fruits and Vegetables

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Background

The concept of quality reflects a measure of excellence, a high standard, or value. In the context of food, quality encompasses the attributes of a product that influence its acceptability to consumers. Attributes such as texture, colour, shape, size, sugar content, and nutritional value are critical in determining the quality of agricultural products. These factors play a pivotal role in consumer preferences and market acceptance, which in turn directly or indirectly impact storage, transportation, and postharvest processing operations.

Traditional methods to assess the quality of fruits and vegetables, such as destructive testing and evaluations by trained panels, are considered reliable but are often labour-intensive, time-consuming, and expensive. Additionally, these methods usually require specialised sample preparation. With the growing consumer demand for high-quality food products, producers are increasingly adopting reliable, rapid, non-destructive, and non-invasive techniques for determining fruit and vegetable maturity, especially during harvesting and packaging processes.

Introduction

Non-destructive analysis refers to methods that test the quality of fruits and vegetables without invasive procedures that could alter their physical or chemical properties. This approach ensures that the integrity and quality of the food remain intact while providing critical information about its attributes. Non-destructive techniques are particularly useful for large-scale agricultural operations, offering a balance of efficiency, accuracy, and minimal waste (El-Mesery et al., 2019).

Quality Factors of Fruits and Vegetables

The quality of fruits and vegetables is determined by a combination of external and internal factors.

External Quality Factors (Cakmak, 2019)

- **Size and Shape**: Uniformity in size and shape enhances visual appeal and marketability.
- **Colour**: Includes visual colour, glossiness, and effects of environmental conditions like sunburn.
- **Defects and Bruises**: Indicators such as punctures, cuts, scalds, cracks, and splits can signal reduced quality.
- **Foreign Materials**: Presence of contaminants such as soil, pesticides, and insects.

Internal Quality Factors (Cakmak, 2019)

- **Maturity**: Determines readiness for harvest and optimal consumption.

- **Texture**: Includes parameters like firmness and mealiness.
- **Nutritional Composition**: Encompasses total soluble solids, acidity, sugar, and anthocyanin content.
- **Internal Defects or Diseases**: Issues like browning, chilling injuries, hollows, pits, rot, and microbial spoilage.
- **Chemical Contaminants**: Pesticides, mycotoxins, and other harmful substances.
- **Taste and Aroma**: Critical factors influencing consumer acceptance.

Non-Destructive Methods of Quality Evaluation

Advancements in technology have led to the development of several non-destructive techniques for quality assessment. These methods provide accurate and rapid evaluations while maintaining the integrity of the produce.

Spectroscopic Methods

- **Nuclear Magnetic Resonance (NMR)/Magnetic Resonance Imaging (MRI)**: Provides detailed insights into internal structures and composition.
- **Hyperspectral Imaging**: Captures spectral information across multiple wavelengths for precise quality assessment.
- **Near-Infrared (NIR) Spectroscopy**: Identifies chemical properties such as sugar and water content.
- **Raman Spectroscopy**: Analyses molecular vibrations to detect chemical compositions and contaminants.

X-ray Computed Tomography (CT)

- Offers high-resolution imaging to detect internal defects such as hollow structures, pits, or rot.

Mechanical Methods

- **Acoustic Vibration Response**: Evaluates firmness and ripeness based on sound frequency responses.
- **Impact Force Response**: Measures the resistance of fruits and vegetables to applied force, providing data on texture and maturity.
- **Ultrasonic Methods**: Uses sound waves to assess internal structures and detect defects.

Conclusion

The increasing demand for high-quality, safe, and visually appealing agricultural products has driven the adoption of advanced non-destructive quality assessment methods. These techniques not only ensure the preservation of food integrity but also address the need for rapid and reliable evaluations. With continuous innovation, non-destructive technologies hold the potential to revolutionise quality control practices, benefiting producers, consumers, and the environment alike.

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5. NANOTECHNOLOGY

Application of Carbon Nanotubes

C. SHARMILA RAHALE

Carbon nanotubes (CNTs) are cylindrical structures made of carbon atoms arranged in a hexagonal pattern. Due to their unique properties, such as remarkable strength, electrical conductivity, and thermal stability, CNTs have a wide range of applications across various industries. Here are some of the most promising applications of carbon nanotubes:

Electronics and Electrical Devices

a. **Transistors**: CNTs are used to make smaller, faster, and more efficient transistors for electronics, potentially replacing silicon-based transistors as they scale down in size. Their high electrical conductivity and ability to carry current without significant power loss make them ideal for advanced computing and nanoelectronics.
b. **Superconducting Materials**: When functionalized, CNTs can exhibit superconducting properties, making them useful in applications requiring high-efficiency power transmission or magnetic resonance imaging (MRI) systems.
c. **Conductive Films**: Carbon nanotubes can be used to create transparent, flexible, and highly conductive films for use in displays, touch screens, and photovoltaic cells.

Energy Storage and Conversion

a. **Batteries**: CNTs are used in advanced batteries, including lithium-ion and supercapacitors, to improve energy density, charge/discharge rates, and overall performance. They can enhance the conductivity of the electrodes and help increase the lifespan of the battery.
b. **Solar Cells**: CNTs are used in the development of more efficient organic solar cells and thin-film solar panels due to their excellent electrical conductivity and light absorption properties.
c. **Fuel Cells**: Carbon nanotubes can serve as efficient catalysts or catalyst supports in hydrogen fuel cells, improving their efficiency and reducing costs.

Composites and Materials Science

a. **Lightweight, Strong Materials**: CNTs are added to polymers, metals, and ceramics to create composites with exceptional strength-to-weight ratios. These composites are used in aerospace, automotive, and construction industries for lightweight, durable materials.
b. **Armor and Protective Gear**: The strength of CNTs makes them ideal for creating materials for ballistic protection, including body armor and protective shields.
c. **Structural Materials for Space**: Due to their strength and low weight, CNTs are being researched for use in spacecraft, satellite components, and other space exploration materials.

Medical Applications

a. **Drug Delivery**: CNTs can be functionalized to carry drugs directly to specific cells or tissues in the body, offering a more targeted approach to treatment. This can improve the efficacy of drugs while minimizing side effects.
b. **Medical Imaging**: CNTs are used in bioimaging applications, such as in MRI and optical imaging, due to their ability to enhance signal detection.
c. **Biosensors**: CNTs are used to develop highly sensitive biosensors for detecting diseases, toxins, or other biological markers. Their high surface area and conductivity make them ideal for rapid and accurate biosensing applications.

Environmental Applications

a. **Water Purification**: CNTs can be used in water filtration systems to remove heavy metals, organic contaminants, and bacteria from water. Their porous structure makes them highly effective at trapping pollutants.
b. **Air Purification**: CNTs are being researched for use in air filtration

systems to remove pollutants such as carbon dioxide, volatile organic compounds (VOCs), and particulate matter from the air.

Sensors and Actuators

a. **Gas Sensors**: Due to their high surface area and sensitivity to environmental changes, CNTs are used in gas sensors for detecting toxic gases, such as carbon monoxide, nitrogen oxides, and methane, which is critical for industrial safety.
b. **Flexible Sensors**: CNTs are integrated into flexible electronics to create stretchable, lightweight, and highly sensitive sensors that can be used for health monitoring or in wearable devices.

Nanotechnology and Manufacturing

a. **Nanoelectronics**: CNTs are a key material in the development of molecular electronics, where they can function as conductors, semiconductors, or even magnetic materials in tiny, high-performance electronic circuits.
b. **3D Printing**: Carbon nanotubes are used in 3D printing to create advanced materials with properties like high strength, thermal stability, and electrical conductivity. They can enhance the performance of printed parts in automotive, aerospace, and other engineering sectors.

Textiles and Wearables

a. **Conductive Fabrics**: CNTs are incorporated into fabrics to create conductive textiles used in wearable electronics, such as smart clothing, which can monitor health metrics like heart rate or temperature.
b. **Strengthened Fabrics**: CNTs can be woven into fabrics to make lightweight, durable, and tear-resistant materials for use in clothing, sports gear, and other applications requiring high strength.

Catalysis and Chemical Engineering

a. **Catalysts for Chemical Reactions**: Carbon nanotubes are used as catalysts or catalyst supports in chemical processes, such as in petroleum refining, fuel production, and other industrial applications, due to their high surface area and ability to accelerate reactions.
b. **CO2 Capture**: CNTs are being studied for their ability to capture and store carbon dioxide from industrial emissions, helping to mitigate the effects of climate change.

Space and Aerospace

a. **Structural Materials for Spacecraft**: CNTs are used in the development of advanced composite materials for spacecraft, satellite components, and space stations. Their combination of lightness and strength helps reduce the weight and improve the durability of space structures.
b. **Thermal Protection**: Carbon nanotubes can be used in thermal protection systems for spacecraft to manage the extreme heat generated during re-entry or exposure to the sun.

Carbon nanotubes hold enormous potential across a wide range of fields due to their unique properties. They enable advancements in materials science, energy storage, medicine, and more, promising to revolutionize industries and lead to more efficient and sustainable technologies. However, further research and development are needed to overcome challenges related to their large-scale production, functionalization, and integration into real-world applications.

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6. HORICULTURE: POST HARVEST TECHNOLOGY

Ozone as a Powerful and Sustainable Disinfectant and

Its Application in Food Processing

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Introduction:

Ozone (O_3) is a molecule comprising three oxygen atoms, renowned for its remarkable oxidizing properties. It effectively eliminates microorganisms by inducing oxidative stress, a process that damages critical cellular components such as proteins, lipids, and genetic material. This multi-pronged attack disrupts essential functions, leading to microbial death. Importantly, ozone's mechanism targets multiple pathways, making it exceedingly difficult for microorganisms to develop resistance-a key advantage over conventional chemical disinfectants. Studies consistently affirm ozone's effectiveness. For example, research conducted in 2017 revealed that even after prolonged exposure, bacteria did not develop resistance to ozone, maintaining their susceptibility. Similarly, viruses exposed to ozone showed no evidence of adaptation, confirming its robust antimicrobial potential. These attributes make ozone a reliable choice for combating a wide array of pathogens. Beyond its antimicrobial prowess, ozone offers several environmental and operational benefits. It decomposes quickly into oxygen, leaving no harmful residues or byproducts, making it eco-friendly (Bermúdez-Aguirre and Barbosa-Cánovas, 2016). Its short half-life ensures minimal environmental persistence, reducing long-term impact. Moreover, ozone's ability to treat both air and water enhances its utility in diverse applications, from healthcare to food safety.

Properties and Production

Designated as Generally Recognised as Safe (GRAS) by the US FDA in 2001, ozone has been widely adopted in industries such as food processing, water treatment, and air purification. Its production is typically on-site using methods like:

1. **UV Radiation**: Air or oxygen is exposed to ultraviolet light at a wavelength of 285 nm, splitting oxygen molecules to form ozone.
2. **Corona Discharge**: High-voltage alternating current creates a discharge in the presence of air or oxygen, efficiently generating ozone. Using pure oxygen improves efficiency by reducing nitrogen oxide byproducts.
3. **Other Methods**: Thermal, chemical, nuclear, electrochemical, and electrolytic techniques are also employed, tailored to specific industrial needs.

Biocidal Action of Ozone: The antimicrobial power of ozone stems from its high oxidation-reduction potential (+2.07V), enabling it to disrupt and degrade bacterial, viral, and fungal cells. Ozone's oxidative properties affect multiple cellular structures:

- **Cell membrane**: Oxidises unsaturated lipids, weakening membrane integrity.
- **Proteins**: Alters protein structures, impairing their functions.
- **Genetic material**: Damages DNA and RNA, preventing replication.
- **Defensive enzymes**: Inactivates catalase and superoxide dismutase, disabling microbial protective mechanisms.

The oxidative action is bolstered by reactive oxygen species (ROS), including hydroxyl radicals, singlet oxygen, and hydrogen peroxide. These secondary oxidants enhance ozone's efficacy by attacking cellular components non-selectively, leading to complete cell lysis.

Factors influencing Ozone Efficacy

1. **Temperature**: At higher temperatures, ozone's solubility decreases, but its reaction rate with microorganisms increases. Cold storage conditions enhance antimicrobial activity, making ozone particularly effective for chilled produce.
2. **pH Levels**: Ozone is more stable in acidic conditions but decomposes rapidly in alkaline environments. Higher pH values promote free radical formation, enhancing

disinfection at the cost of ozone stability.

3. **Humidity**: High humidity (above 90%) increases ozone's solubility and efficacy on moist surfaces. Hydrated microbial cells are more susceptible to ozone than desiccated ones.
4. **Organic Matter**: Organic compounds in water or on surfaces consume ozone, reducing its availability for microbial disinfection.
5. **Microbial Characteristics**: Gram-positive bacteria, with thicker cell walls, show greater resistance than gram-negative bacteria. Spores and microorganisms with robust protective structures are more resilient but still vulnerable to prolonged exposure.

Applications in Food Processing: Ozone's application in the food industry, particularly for cut fruits, highlights its versatility and effectiveness. Treating cut fruits with aqueous ozone—a water-based solution infused with ozone gas offers the following advantages:

1. **Microbial Decontamination**: Aqueous ozone significantly reduces bacterial and fungal contamination, ensuring safer consumption.
2. **Preservation of Freshness**: By reducing microbial load and oxidative spoilage, ozone extends the shelf life of fresh produce without affecting sensory qualities.
3. **Eco-Friendliness**: Unlike traditional chemical disinfectants, ozone decomposes into oxygen, leaving no harmful residues or byproducts.
4. **Compliance with Safety Standards**: Ozone meets stringent food safety requirements, aligning with industry demands for clean and sustainable solutions.
5. **Flexible Application**: Methods such as spraying, dipping, or washing can be tailored to the type of fruit and desired level of decontamination.

Conclusion

Ozone represents a breakthrough in disinfection technology, combining unmatched antimicrobial efficacy with environmental sustainability. Its ability to target multiple cellular structures prevents the emergence of microbial resistance, offering a significant advantage over traditional methods. Whether used for air, water treatment or food processing, ozone is a versatile and eco-friendly solution supporting modern industry goals. Embracing ozone not only ensures safety and quality but also reflects a commitment to preserving environmental integrity.

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7. NANOTECHNOLOGY

Nanotechnology in Space

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Nanotechnology is a science and engineering field concerned with the creation of 'things' on the atomic and molecular scale – typically, materials and devices. One-billionth of a meter is a nanometre: ten times the diameter of an atom of hydrogen. On average, the width of a human hair is 80,000 nanometres. The normal laws of physics and chemistry are no longer applicable to such scales.

Nanotechnology in space refers to the use of nanoscale materials, devices, and systems in space exploration, research, and technology development. Nanotechnology is particularly promising in space applications due to its ability to enhance the performance, reduce the weight, and improve the efficiency of spacecraft and instruments.

Military Applications

For use in the defense industry, nanotechnology applications hold strong promises. The latest thinking is that nanotechnology can be used by soldiers in two main ways. The first is the miniaturization of existing equipment so that it is not only smaller, but also lighter consumes less energy, and can be hidden more easily. The second is to invent new materials for military use and adapt them.

In outer space, nanotechnology will have endless possibilities. Usage of nanotechnology for substantially smaller satellites, along with smaller launch vehicles, to begin with. Therefore, they make these satellites cost-effective. Also, these nano-satellites could be used for radar, communication, and intelligence in swarms. Such satellites could also facilitate high resolution dedicated images of enemy territories.

The suit's polymer molecular muscle ribbons can amplify the resilience of a soldier up to ten times. At current, in most battlefield applications, the muscles are slow to react and thus not practical. For safety against bullets and other ballistics, Kevlar is already the material of choice and nanotechnology is being implemented to even further enhance its functionality. Five times stronger than steel and more than twice as strong as any other shock absorbent material currently in use, testing is ongoing on a shock-resistant material.

Another military use for nanotechnology is high-strength, highly durable coatings to enhance sturdiness, corrosion resistance, and reliability. These materials can sense damage or corrosion and activate repair of some damage instantly. The possibilities for coatings to change color when necessary is also there. This could include evolutionary camouflage for tanks moving into urban areas or from the jungle to open fields.

In both the civilian and military research realms, nanotechnology finds applications. Many nanotechnology applications are being developed in the civilian realm, which could soon find a place in the military arena. National states are working rigorously to develop capabilities in the region. It, therefore, needs stringent steps from the Indian side to be up to date with the technology.

Aerospace Applications

High-strength low-weight composites, advanced electronics, and screens with low power consumption, a range of physical sensors, multipurpose materials with embedded sensors, large surface materials, and modern air purification filters and membranes are among the aerospace applications for nanotechnology.

Some of the key areas where nanotechnology is making an impact in space include:

1. **Lightweight and Strong Materials:** Nanomaterials, such as carbon nanotubes and graphene, are incredibly strong yet lightweight. These materials can be used to construct spacecraft, satellites, and other space infrastructure, reducing the mass and improving fuel efficiency. The high strength-to-weight ratio can also provide better resistance to harsh conditions in space.
2. **Spacecraft and Satellite Components:** Nanotechnology can improve various components of spacecraft and satellites:
    a. **Nanocoatings**: These coatings can be applied to protect against radiation, micrometeoroids, and the extreme temperature fluctuations in space.
    b. **Nanoelectronics**: Small, efficient electronic components allow for smaller, lighter, and more reliable spacecraft systems.
    c. **Nanostructured solar cells**: These are more efficient than traditional solar cells, allowing spacecraft to generate more power with less space.
3. **Space Propulsion:** Nano-engineered materials can enhance propulsion systems in space exploration. For example, nanomaterials can improve fuel efficiency and thermal management in ion thrusters and chemical rockets, potentially reducing the cost and increasing the reach of missions.

4. **Sensors and Imaging Systems:** Nanotechnology is helping develop highly sensitive sensors and imaging systems for space research. Nanomaterials can be used to create advanced detectors that are capable of observing distant celestial bodies, analyzing chemical compositions, and studying phenomena like dark matter and black holes with high precision.
5. **Medical Applications:** Nanotechnology can play a role in ensuring the health of astronauts during long-duration space missions. Nanomaterials can be used in medical devices to monitor astronaut health, deliver drugs more efficiently, and protect against radiation exposure by developing better protective gear or medication.
6. **Space Manufacturing:** Nanotechnology can be used for in-space manufacturing, potentially allowing astronauts to create tools and parts from local materials on other planets or moons. This technology could reduce the need for transporting all necessary equipment from Earth.
7. **Space Habitat Systems:** Nanotechnology can help develop better life support systems for space habitats. Nanomaterials may be used in filtration systems to purify air and water, improving the quality of life for astronauts and making habitats more sustainable.
8. **Space Exploration Tools:** Small, portable, and efficient nanotechnology-based tools can support exploration on planets and moons, especially where traditional equipment may be too bulky or cumbersome. These tools can be used for surface analysis, digging, drilling, or even collecting samples with minimal weight and power consumption.

Occasionally astronauts have to leave their spaceships, so researchers at Northeastern University and Rutgers University propose that we protect the astronauts by including layers of bio-nano robots in their spacesuits. The outer layer of bio-nano robots would respond to damages to the spacesuit, for example to seal up punctures. An inner layer of bio-nano robots could respond if the astronaut was in trouble, for example by providing drugs in a medical emergency.

The term bio-nano robots comes from the use of biological molecules to provide portions of the robots mechanism. For example, proteins have mechanisms to travel within a body that enable it them to work as a motor for a nano robot. These proteins could be connected to carbon nanotubes that link parts of the nano robot together. When you think about it, this idea is just like harnessing a horse to a cart as the nano robots hitch a ride on the proteins. There’s a lot of development work to be done, but it will be interesting to see how these self-healing suits turn out.

In summary, nanotechnology has vast potential for revolutionizing space exploration by making missions more efficient, safe, and sustainable. The continued development of nanotechnology will likely play a crucial role in future endeavors, from satellite systems to manned missions to Mars and beyond.

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8. PLANT BREEDING AND GENETICS

Wide Hybridization in Pigeon Pea

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Introduction

Pigeon pea [*Cajanus cajan* (L.) Millsp.] belongs to the family *Fabaceae*. It is diploid (2n = 2x = 22) and often cross pollinated (20-70%) crop. According to Van der Maesen (1980)Pigeonpea originated from its wild progenitor *Cajanus cajanifolius* in central India 4000 BCE. From there, it was spread East Africa, Malaysia followed by Egypt then West Africa and finally to the America. It arrived in the New World with the slave trade. Most acceptable centre of origin is India. It is the sixth most important grain legume in the world and second most important pulse crop after chickpea in India. Globally, it is cultivated on a 5.4 million hectaresland area with an annual production of 4.49 million tons.It is grown in about 82 countries in the world.India accounts for about 75% of the area and about 72% production for pigeonpea(Fatokimi and Tanimonure, 2021).

Wide Hybridization

"Wide hybridization or distant hybridization is crossing between two different species belonging to same genera or different genera." Such crosses are called wide crosses or distant crosses.

Role of Wide Hybridization

- Broaden the gene pool3. Enhance resistance to stresses
- Utilization as new varieties4. Improve quality characteristics

Case Study

Singh *et al.* (2018) evaluated BC_1F_2 and F_3 populations derived through wide hybridization for yield and component traits in pigeon pea.wild species *C. scarabaeoides* accession ICP 15683 had poor performance but it had contributed desirable alleles for increased number of fruiting branches, pods per plant and reduced plant height which have been introgressed in the cultivated pigeon pea. Seed yield per plant had highly significant and positive association with pods per plant and fruiting branches per plant.

Singh *et al.* (2020)conducted an experiment aimed at introgression of productivity enhancing traits and resistance to pod borer and Phytophthora stem blight from wild to cultivated pigeon pea through an inter-specific cross between *Cajanus scarabaeoides* (ICP 15683) and *C. cajan* (ICPL 20329). Introgressed progenies having higher fruiting branches, pods and yield per plant compared to the cultivated parent were identified in both populations. Progenies from both the populations were identified with higher resistance to pod borer and Phytophthora stem bligh.

Swamy *et al.* (2024) conducted an experiment on deciphering the G x E interaction involved in milling quality of pigeon pea (*Cajanus cajan*) derived from interspecific hybridization.In India, about 80% of the pulses produced are eaten as dhal (dehusked splits), recovery of dhal plays a major role in the pulse milling industry. The genotype G12 derived from the UPAS120 x *C. cajanifolius* was found most stable genotype with high dhal yield and hulling efficiency.

Ngugi-dawit *et al.* (2020) conducted an experiment to investigated insect-resistance components in IBS 3471, a *C. scarabaeoides* accession, and explored the possibility of transferring resistance mechanisms to cultivated pigeon pea. This study demonstrates that IBS 3471 has multiple resistance mechanisms against *H. armigera,* and they are transferable to cultivated pigeon pea.

Saxena *et al.* (2023) conducted an experiment on breeding high-protein pigeon pea genotypes and their agronomic and biological assessments. For that, high-protein trait was successfully transferred from wild relatives of pigeon pea to the cultivated types. In the derived inbred lines, the protein content was significantly enhanced from 20% - 22% to 28% - 30% and also having high nutritional and biological value with no yield penalty.

Conclusion

- Wild species *C. scarabaeoides* accession ICP 15683 had desirable allele for higher fruiting branches and pods per plant which can be introgressed into cultivated pigeon pea
- Wild species *C. scarabaeoides* possesses many desirable traits for productivity enhancement, resistance to pod borer and PSBwhich can be successfully introgressed into cultivated pigeon pea. Lines, BCP 11 and DSP 12 can be used in further breeding programmes
- Genotype G12 derived from *C. cajanifolius* was found to be more stable for dal yield and hulling efficiency so G12 genotyope is used for genetic improvement of milling quality in future breeding programme
- Wild species *c. scarabaeoides* having a resistant trait and this trait is

transferable to next generation so we can used *c. scarabaeoides* to improve insect resistant in large scale breeding programme

- Wild species *c. scarabaeoides*, *c. albicans*, *c. sericeus* were used for genetic enhancement of seed protein in pigeon pea which also having high nutritional and biological value with no yield penalty

Future Prospects

- Focus should be given on broadening of the genetic base of pigeonpea hybrids by identifying a greater number of compatible wild species
- Hybrids with early and synchronous maturity along with short stature and higher yields should be developed
- Efforts should be made to develop varieties tolerant to waterlogging and cooler temperatures, enabling cultivation in both rainy (*Kharif*) and post-rainy seasons (rabi)
- Efforts should be made to develop drought tolerant varieties enabling cultivation in dry land areas where irrigation facilities are not possible
- Combining traditional breeding techniques with modern biotechnological approaches can help address challenges in global agriculture

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9. POST HARVEST TECHNOLOGY

Biofortification in Crops with Special Reference to Pulses

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Introduction

Malnutrition is a condition that results from eating a diet in which one or more nutrients are either not enough or are too much such that the diet causes health problems. Malnutrition caused by deficiencies of vitamins and minerals - also called Hidden hunger. Hidden hunger (deficiencies in micronutrients) is emerging as a major challenge for agricultural scientists. It is caused by lack of vitamin A, zinc, iodine, folate and iron (Jawaldeh *et al.* 2019). World population is increasing, and food consumption demand is augmenting**.**

Biofortification:

The term coined by Steve Beebe, a bean researcher at the international center for tropical agriculture (CIAT), in 2001.Biofortification is a method of breeding crops to increase their nutritional value. Biofortification can be defined as a process to increase the bioavailability and the concentration of nutrients in crops through both conventional plant breeding and recombinant DNA technology (genetic engineering) (White and Broadley, 2005).

Harvest Plus:

Harvest Plus is the part of CGIAR Research Program on Agriculture for Nutrition and Health. Harvest Plus was formally launched in the year 2004.It coordinated by two CGIAR centers, CIAT and IFPRI.

Harvest Plus has operated in India since 2011, in close collaboration with partners in the public and private sector, to improve nutrition and public health by developing and promoting biofortified crops and building out biofortified seed and crop value chains.

Case Studies

Ning *et al.* (2014) detected the genetic loci in recombinant inbreed line population of soybean for mineral concentrations, including calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and phosphorus (P).They detected many loci which were associated with micronutriens.

Babu and Neeraja (2017) investigated several rice varieties and land races collected from different parts of the country. Among them, about 10 varieties each with high iron and zinc content were identified and some of these lines were used in the breeding programme to develop nutritional rich genotype.

Kumar *et al.* (2019) reviewed genetic transformation of crops like rice, wheat, maize, cassava and canola for zinc, iron and vitamin A enhancement in the edible part of the crops. The researchers concluded that gene technology is a rewarding method for the development of nutrient dense crops.

Pessoa *et al.* (2021) evaluated the nutritionally potential and indicated genotypes of cowpea (*Vigna unguiculata*) for genetic improvement based on nutritional traits. The CE-0151, CE-0189, CE-0207, CE-0228, CE-0248, CE-0542, CE-0685, CE-0686, CE-0796, CE-0997, and CE 1002 genotypes are indicated for selection to continue the biofortified cowpea breeding program.

Singh *et al.* (2021) determine the potential of parents (PKG 2, ICC 19, ICC 21, ICC 22 and ICC 24) and their crosses for Zn and Fe micronutrient content through diallel cross. Heterosis was also estimated to identify superior combinations. Out of 10 crosses, a cross PKG 2 × ICC 19 showcased significant positive heterosis over mid, better and check parents for Fe content and ICC 19 × ICC 24 depicted superiority over mid and better parents for Zn content. Hence, crosses PKG 2 × ICC 19 and ICC 19 × ICC 24 could be found beneficial in biofortification programme in combating nutrient deficiency.

Shahin *et al.* (2022) identified LR-9-25 (BARI Masur-8) lentil line from RIL population created through a cross between ILLX955-135 and FLIP92-52L. BARI Masur-8 showed high yield potential (1,973 kg ha^{-1}) and high concentrations of Fe (74 mg kg^{-1}) and Zn (61 mg kg^{-1}) in seed.

Akhtar *et al.* (2023) performed line × tester analysis for the assessment of heterosis for grain yield, iron and zinc content in six lines and three testers of maize. The experiment was performed in two environmental conditions *viz.,* optimum N and low N condition for better results. Both additive and non-additive gene effects were found important for controlling iron, zinc and grain yield, while high and positive sca effect for these traits in low N condition leads to the development of promising research hybrids for low N areas.

Freitas *et al.* (2023) evaluated the potential of 100 cowpea genotypes for biofortification of iron, zinc, and proteins, and cooking quality of the grain. The superiority of genotypes for iron, zinc, proteins, and cooking quality was carried out using the nutritional quality and cooking index. The line MNC11-1023E-28 has the best profile of nutritional and cooking quality, showing potential as a food to meet consumer demands and reverse iron and zinc deficiency in the Brazilian population.

Conclusion

Nutrients dense crops developed through plant breeding approaches (biofortification) is now well established as cost effective and sustainable approach to minimize nutritional gaps

Limited extent of genetic variability in available breeding material and complexity in obtaining healthy, fertile recombinant restricts further nutritional gain in pulses, unlike other developed biofortified crops

The unexplored wild and related species of crops, can be incorporated in breeding programme as potential source of genetic variability to develop nutrient dense variety of a crop with competitive yield

In parallel to conventional breeding, gene technology and marker assisted breeding can also be adopted, for the development of nutrient dense crops

Future Thrust

- Developing biofortified varieties that are resilient to climate change will ensure stable production even under changing environmental conditions
- Through gene stacking, combining multiple nutritional traits in a single crop variety can address multiple nutrient deficiencies simultaneously
- Development of hand-held and easy to use equipment that can quickly provide some reliable estimates of the quality parameters of the produce would be beneficial (like brix meter in sugarcane and sweet corn).
- Bio-efficacy and acceptability trials of the biofortified varieties, need to be designed more often, to confirm the suitability of the variety to the end user besides developing confidence
- Assured premium remunerative price through minimum support price for biofortified produce in the market will encourage the farmers to grow more biofortified crops

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10. AGRICULTURAL EXTENSION

Role of Subject Matter Specialist in Krishi Vigyan Kendra

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In India, efforts of agricultural extension are largely deployed by government and some extent through non-government agencies. These extension efforts have largely been taken up by the state departments of agriculture and other disciplines as a state subject. The Indian Council of Agricultural Research (ICAR) works as the apex body to provide new technologies in agriculture and allied aspects through transfer of technology. In year 1974, based on the recommendation of the Education Commission (1964-66), discussion by the Planning Commission and Inter-Ministerial Committee, and further recommendation by the committee headed by Dr. Mohan Singh Mehta appointed by ICAR in 1973 the idea of establishment of Farm Science Centre (Krishi Vigyan Kendra) was developed. These KVKs work as the organizations of frontline extension system which play their tremendous role to meet the information needs of farmers in all aspects related of their daily activities including home science and home economic practices. They have to serve as repository of scientific information and various agricultural materials which are useful to the entire district of its jurisdiction. In our country, almost every district has its own KVK so we can say that the jurisdiction of the KVK is one whole district. Sometimes some districts have more than one KVK which mainly depend upon the size or area of the district.

When we see the staffing pattern of KVKs, we can find experts of every discipline of agriculture and allied sectors. These experts are popularly known as subject matter specialist (SMS). Generally, every KVK consists of total six SMS of various subjects i.e. crop production, crop protection, extension education, horticulture, home science and animal science. Recently, some KVK consist the specialist of agro-meteorology discipline too. These all SMSs work under the leadership of senior scientist and head of KVK and under the guidance of Director of Extension Education of respective host universities. The role of the SMSs is varied in nature according to their specialization. For e.g. specialist of animal science mainly deals with live stock related activities that others generally don't. But one thing which is common for every SMSs are that they all have to follow the mandatory activities of KVK. Here, we will see some major roles performed by subject matter specialists in KVK:

1. Role of conducting frontline demonstrations (FLDs): Every SMS of KVK have to select farmers for arranging the FLDs on their fields with a view to create an awareness about the new technology and showing the results of that with a view to enhance their knowledge and adoption, changing their attitude and improve their skill to perform various operations. Here, SMSs follow the principles of learning by doing and seeing is believing of extension education. After completion of FLDs they arrange the field day on farmer's place.
2. Role of conducting the on farm testing (OFT): For the assessment of new technology in new area and refine that technology according to that area, SMSs organize the on farm testing on farmers' field.
3. Role of providing the training: SMSs of KVK have to give the on campus as well as

off campus and vocational training to farming community, extension personnel of other departments as well as rural youth to update their knowledge, improve their skills and change their attitude. They deliver well prepared and useful lectures for extension workers. They conduct demonstrations, organized workshop, provide direct training to interested groups i.e. ASCI training and serving as resourceful person in highly complex problem-solving areas.

4. Role of producing and selling the seeds/agriculture inputs and planting materials: KVK as a knowledge and resource centre, experts of it produce various seeds and planting materials and selling them to farming communities.
5. Role of organizing and execution of various extension programmes: SMSs of KVK involve in preparation of various extension programmes. They involve in fixation of objectives, selection of proper method or procedure for execution of programme, work as knowledgeable persons about how to interpret the collected information and use of results revealed by evaluation and field studies.
6. Role of utilizing of various ICT tools and services for well being of farming community: Now a days, into the era of information and technology, these experts utilize the various mass media to disseminate various information. E.g. they usually prepare various WhatsApp groups of farmers and timely share the information in simplest form, deliver radio talk, and arrange various online video lectures through various online platforms.
7. Role of subject matter authority: They are having with thorough knowledge in their area of specialization and they are considered as most authentic source of information at their level. They serve as a liaison with research and are having with knowledge of trends. They possessing a broad knowledge of the entire extension programme and the role played by their subjects of specialisation.
8. Role of maintain the relationships: They maintain the good relationship with the groups of farmers, extension workers and staff members of other govt departments. They cooperate at all levels in developing "package programmes" and appreciate the work of other specialists. They understand very well the concept of integration of teaching, research and extension. They coordinate with other staff members of KVK and believe in achieving team spirit.
9. Role of preparation of various extension literature: They prepare various extension literatures like leaflets, folders, books, training manuals, bulletins, newsletters, etc consisting the information of various recommended practices, results of various researches conducted by KVK, success stories of farmers, press notes in newspapers etc.

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11. SOIL SCIENCE

Zero Budget Natural Farming "Back to the Basics"

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Introduction

Agriculture has been the backbone of the Indian economy for centuries. More than half of the country's population depends on agriculture and allied services for their livelihoods. Green revolution led to the increase in production of crops but it emphasized on the increased use of external inputs like high yielding variety seeds, agrochemical like fertilizers and pesticides and intensive agronomic practices. These methods helped in increasing production at the beginning stages but later its adverse impact started to appear. Farmers' distress and agricultural crisis due to inefficient extension activities, environment degradation and degrading soil quality and debt cycles due to high input costs started to become visible in Indian Agriculture System. Padam Shri Subhash Palekar ji came up with an idea of Zero Budget Natural Farming. In this farming practice, emphasis was laid on the locally available inputs and dependency on external inputs was reduced. The ZBNF farm model is based on polycropping. The expenditure on the main crop is recovered from the income from the short duration inter crops; so that the net expenditure on the main crop is 'zero'. By the use of cow dung and cow urine of indigenous breeds is prompted in this system of farming. With reduced use of chemicals in the farmlands soil micro biome rejuvenated and aided in the production of higher yields. The word Zero Budget related to the zero net cost of production of all crops (border crops, inter crops, multi crops). This means that farmers need not buy fertilizers and pesticides for the purpose of the healthy growth of crops.

Four Wheels of ZBNF

1. **Jivamrita:** jeevamrutha is a fermented microbial culture that adds nutrients to the soil, and acts as a catalytic agent to promote the activity of microorganisms and earthworms in the soil. Jeevamrutha a mixture of fresh desi cow dung and aged desi cow urine, jaggery, pulse flour, water and soil — on farmland. During the 48 hour fermentation process, the bacteria in the cow dung and urine multiply by feeding the pulse flour in the solution. Virgin soil is added to inoculate native bacteria and other organisms. Jeevamrutha helps to prevent plant diseases. This is required in the first 3 years of the transition.
    - Application: 200 liters of Jeevamrutha is sufficient for one acre of land. Apply twice a month with irrigation water or as 10% foliar spray.
2. **Bijamrita:** Beejamrita is used for seed, seedlings and any planting material treatment. It is composed of –local cow dung, a powerful natural fungicide, and a strong anti- bacterial liquid, cow urine, lime soil. Bijamrita is effective in protecting young roots from fungus as well as from soil-borne and seed borne diseases that commonly affect plants after the monsoon period.
3. **Acchadana (Mulching):** there are three types of mulching:
    a. Soil Mulch: This protects topsoil during cultivation and does not destroy it by tillage operations. It promotes water retention and aeration in the soil.
    b. Straw Mulch: Straw material usually refers to the dried biomass waste of previous crops, but it can be composed of the dead material of any living being (plants, animals, etc). Soil fertility provides dry organic material which will decompose and form humus through the activity of the soil biota which is activated by microbial cultures.
4. Live Mulch (mixed crops and symbiotic intercrops): It is essential to develop multiple cropping patterns of monocotyledons and dicotyledons grown in the same field, to supply all essential elements to the soil and crops. For instance, legumes are of the dicot group and are nitrogen-fixing plants. Monocot plant residues supply other elements like potash, phosphate and sulphur.
5. **Whapasa (moisture):** Plant roots need a lot of water, thus countering the over reliance on irrigation in green revolution farming. Whapasa is the condition where there both air molecules and water molecules present in the soil, and he encourages reducing irrigation only at noon, in alternative furrows ZBNF farmers describe a significant decline in need for irrigation in ZBNF.

Other Important Points

- **Cow dung**- Dung from the Bos indicus (humped cow) is most beneficial and has the highest concentrations of micro-organisms as compared to European cow breeds such as Holstein. The entire ZBNE method is centered on the Indian cow, which historically has been part of Indian rural life.

- **Contours and Bunds** – To preserve rain water, make the contours and bunds, which promote maximum efficacy for different crops.
- **Intercropping** – It is basically based on how ZBNF gets its "Zero Budget" name. That any cost making farming near to zero budget activity repaid for by income from intercrops.
- **Earthworm's Species**. Use of vermicompost is most beneficial. The betterment of local deep soil earthworms by increasing organic matter is most useful.

Impacts of Zero Budget Natural Farming (ZBNF)

1. As both an environmental and social programme, it aims to ensure that smallholder farming – is economically viable by improving farm biodiversity and ecosystem services.
2. ZBNF promoted well-bearing for all at all ages and healthy lives.
3. It reduces farmers' costs by the excluding external inputs and using internal resources to rejuvenate soils, whilst simultaneously restoring ecosystem health through diverse and increasing incomes, multi-layered cropping systems.
4. It ensures for the water and sanitation availability and sustainable management.
5. Cow dung from local cows has proven to be a miraculous cure to revive the fertility and nutrient value of soil. One gram of cow dung is believed to have anywhere between 300 to 500 crore beneficial micro-microorganism. These micro-organisms decomposed the dried biomass on the soil and convert it into ready-to-use nutrients for plants.
6. Ensure access to modern energy, affordable, reliable and sustainable for all.
7. Zero budget natural farming requires each 10 per cent water and electricity than what is required under chemical and organic farming. ZBNF may increase the capacity of crops to adapt and be produced for evolving climatic conditions.
8. Promote sustainable, economic growth, sustained employment and decent work for all the resources.

Government initiatives to Support ZBNF

- Government of India has dedicated two schemes in which one ***Paramparagat Krishi Vikas Yojana (PKVY*** 2015-16) and second ***Rashtriya Krishi Vikas Yojana (RKVY)*** to promoting organic farming in the country.
- Various organic farming models like Natural Farming, Homa Farming, Rishi Farming, Vedic Farming, Cow Farming, Zero Budget Natural Farming (ZBNF) etc. have been included in the revised guidelines of ***PKVY scheme*** during the year 2018, wherein choice is given to states to choose any model of organic farming including ZBNF totally depend on farmers choice.
- Under the ***RKVY scheme,*** organic farming/ natural farming project components are considered by the respective State level Sanctioning Committee (SLSC) according to their priority/ choice.

Conclusion

To overcome the farmer's distress and sustained the livelihood Zero budget natural farming has been emerged as farmer's practices for marginal and small holding farmers. It focuses to provide multiple benefits, both to the farmers and environment. Because of continuous incorporation of organic residues and replenishments of soil fertility helps to maintain the soil health.

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12. HORTICULTURE

Greenhouse Technology for Plant Propagation and Production

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Plant propagation is the process of creating new plants from a variety of sources: seeds, cuttings, bulbs and other plant parts. Plant propagation can also refer to the artificial or natural dispersal of plants. Plants can be propagated by two methods, namely – sexual and assexual.

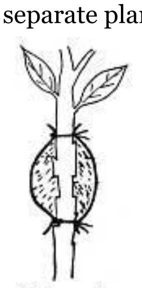
1. **Sexual Propagation:** Seed formation takes place only after pollination. After fertilization, seeds are formed. Seeds when sown give rise to new plants.
2. **Assexual Propagation:** This process is also called as vegetative propagation. Stem cuttings, root cuttings, leaf cuttings, root division, layering, grafting and budding are all vegetative methods of propagation.

a. **Stem Cuttings:** Herbaceous stem cuttings of plants like Dahlia, Mint, Portulaca etc. easily root. They do not need any special treatment. In herbaceous plants tender, growing and leafy sections make better plants. Semi-hard cuttings like Schefflera, Aralia, Philodendrons, Hibiscus can be easily rooted. Hardwood cuttings of Bougainvillea, Ixora etc. can be rooted with good amount of success if root promoting hormones are used. These hormones – normally available in powder form – are applied on the lower end of the cutting.

b. **Root Cuttings:** Some plants like Breadfruit, Curry patta, White Poinsettia and some Jasmines and Ixora can be propagated with root cuttings. Roots of such plants if cut at the plant end and the cut tip of the root if exposed to air will start growing in to a new plant.

c. **Leaf Cuttings:** Entire leaves removed from many succulents and kept in moist sandy medium will sprout plantlets. Echeveria, Kalanchoe, and Sedum are such plants. Herbaceous plants like African violets, Begonia Rex, Peperomia also can be propagated through leaf cutting. Sansevieria, Gasteria and Drimiopsis also can be propagated through entire leaf or by planting leaf sections.

d. **Root Division:** Bamboo, Asparagus and Gerbera plants grow in clumps. This clump can be divided into sections, with each section having some roots. The sections are then planted as separate plants.



e. **Air Layering:** Plants which cannot be propagated with any of the above mentioned methods may respond to layering. Layering actually is a type of stem cutting only. But the difference between the two is that in normal stem cutting the stems are cut away from the mother plant and then they are forced to root. In layering, first the roots are formed on a stem of a mother plant and only after that the stem is cut off and is planted as a new plant. Plants grown from layering will fruit earlier than the ones grown from seeds. Mature or semi-mature branches are selected for layering, depending upon the species.

f. **Stooling:** Stooling is a type of air layering only. In this method the branch from which the ring of bark has been removed, is bent down and the portion of the stem from where the bark was removed is inserted in the ground. A stone is kept on the soil to prevent the branch from springing out of soil. After the roots are formed, the branch is cut off from the plant end. The newly rooted branch then is replanted.

g. **Grafting:** Mango, ChikooAnd Golden Champa are available mostly as grafted plants. These days even Cashew, Jackfruit AndJamun plants are being successfully being grafted. Decorative plants such as hybrid red Mussaenda and cactus plants too are available as grafts. "Stock" is a rooted plant upon which a branch of a desired variety of the plant is grafted. The branch, which is being grafted, is called as "scion". Grafting is done on a stock plant, which has a very strong root system. Chikoo plant is always grafted on a sapling of Rayan (also called as Khirni) tree. Following are some important methods of grafting like Wedge grafting, Side grafting, Veneer grafting, Approach grafting (inarching) and Butt grafting (used for grafting cacti plants).

h. **Budding:** Budding, actually, is a type of grafting only. Howerver, in budding, the scion is in a section of shield-shaped skin along with an eye (lateral axillary bud, not a flower bud). On the stock a "T" shaped cut is given. The skin is opened and the bud is inserted inside the skin. After this, the cut is covered by winding a strip of polythene sheet, keeping only the bud exposed. The growing tip of the stock then is severed. Growth of the grafted bud starts within 15 days. Rose, Bougainvillea, limes and other citrus plants, Hibiscus, Ber can be budded.

Plant Tissue Culture is a collection of techniques used to maintain or grow plant cells, tissues or organs under sterile conditions on a nutrient culture medium of known composition. Plant tissue culture is widely used to produce clones of a plant in a method known as micro-propagation. Different techniques in plant tissue culture may offer certain advantages over traditional methods of propagation, including:

- The production of exact number of plants that produce particularly good flowers, fruits, or have other desirable traits.
- To quickly produce mature plants.
- The production of multiples of plants in the absence of seeds or necessary pollinators to produce seeds.
- The regeneration of whole plants from plant cells that have been genetically modified.
- The production of plants in sterile containers that allows them to be moved with greatly reduced chances of transmitting diseases, pests, and pathogens.
- The production of plants from seeds that otherwise have very low chances of germinating and growing, *i.e.:*orchids and *Nepenthes*.
- To clean particular plants of viral and other infections and to quickly multiply these plants as 'cleaned stock' for horticulture and agriculture.

Plant tissue culture relies on the fact that many plant cells have the ability to regenerate a whole plant (tot-potency). Single cells, plant cells without cell walls (protoplasts), pieces of leaves, stems or roots can often be used to generate a new plant on culture media given the required nutrients and plant hormones.

Applications

Plant tissue culture is used widely in the plant sciences, forestry and in horticulture.

Applications Include

- The commercial production of plants used as potting, landscape, and florist subjects, which uses mere-stem and shoot culture to produce large numbers of identical individuals.
- To conserve rare or endangered plant species.
- A plant breeder may use tissue culture to screen cells rather than plants for advantageous characters, e.g. herbicide resistance/tolerance.
- Large-scale growth of plant cells in liquid culture in bioreactors for production of valuable compounds, like plant-derived secondary metabolites and recombinant proteins used as biopharmaceuticals.
- To cross distantly related species by protoplast fusion and regeneration of the novel hybrid.
- To rapidly study the molecular basis for physiological, biochemical, and reproductive mechanisms in plants, for example in vitro selection for stress tolerant plants, and in vitro flowering studies.
- To cross-pollinate distantly related species and then tissue culture the resulting embryo which would otherwise normally die (Embryo Rescue)?
- For chromosome doubling and induction of polyploidy, for example doubled haploids, tetraploids, and other forms of polyploids. This is usually achieved by application of antimitotic agents such as colchicine or oryzalin.
- As a tissue for transformation, followed by either short-term testing of genetic constructs or regeneration of transgenic plants.
- Certain techniques such as meristem tip culture can be used to produce clean plant material from viruses stock, such as potatoes and many species of soft fruit.
- Production of identical sterile hybrid species can be obtained.

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