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PHOSPHATE SOLUBILIZING MICROORGANISMS: ITS MECHANISM AND ROLE IN SOLUBILIZING PHOSPHORUS IN SOIL

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Phosphorus in soil is present both in organic (phospholipids, nucleic acid, phytin) and inorganic forms; it is mostly taken up by plants in inorganic form as orthophosphate $H_2PO_4^-$ and HPO_4^{2-}. Phosphorous is the major nutrient, and required for plants in energy transfer and storage, root development, seed formation, nitrogen fixation in legumes, improvement of crop quality and in metabolic processes like photosynthesis. This phosphorus (P) content in soil is about 0.05% (w/w) but only 0.1% of the total phosphorus is available to plant because of poor solubility and gets fixed with Al^{3+} and Fe^{3+} in acidic soils and with Ca^{2+} in alkaline soils, making them deficient and unavailable to plants. To correct this deficiency there has been wide used of phosphatic fertilizers throughout the world. However, there is a global concern about the ill effects of chemical fertilizers on the soil and its environment and also the huge cost involved, besides they are neither eco-friendly nor sustainable. In the recent years, progresses are made to deviate from use of chemical fertilizers to exploring the potential of beneficial soil microorganisms and use them as 'biofertilizers'. One such important biofertilizer is the phosphorus solubilizers.

Phosphorus solubilizers are those microorganisms (PSMs) which, through their various mechanisms of solubilization and mineralization are able to convert the unavailable form into bioavailable form facilitating increase uptake by plant roots. P solubilizing microorganisms excrete organic acids such as citric acid, lactic acid, gluconic acid, acetic acid, succinic acid, *etc*. which solubilized P into the soluble form. Soil bacteria belonging to genus *Pseudomonas*, *Bacillus*, *Agrobacterium*, *Azotobacter*, *Rhizobium*, *Enterobacter etc.* and fungi group including *Trichoderma*, *Penicillium*, *Aspergillus*, *Fusarium* and vesicular arbuscular mycorrhiza (VAM) *etc*. have been reported to function as P solubilizers.

Additionally, actinomycetes in the genera *Actinomyces*, *Streptomyces* and *Micromonospora* are also capable of solubilizing inorganic P.

Importance of PSM to Plant Growth

Plants deficient in phosphorus are generally accompanied by symptoms of stunted growth, chlorosis, poor root elongation and development, abnormally dark green color owing to accumulation of carbohydrate. There is a direct form of interaction between plants and microbes as they live in close association. It has been reported that phosphate solubilizing microorganisms contribute to soil P pools, constituting about 0.4% to 2.4% of total P in arable soils. These microbes acting as P solubilizers have synergistic effect and contribute to the overall growth and development of crops. They promote plant growth through production of phytohormones such as auxin, zeatin, gibberellins and cytokinins. These growth promoting hormones helps in seed germination, root elongation, hasten maturity and improve quality of crops. Phosphate solubilizers not only solubilize phosphate but also other micronutrients and trace elements which increase their availability for plant uptake. They also produce siderophores as well as chelate elements and helps in mobilization of nutrients. Besides their role as P solubilizers they also inhibit the growth of phytopathogens by producing antibiotics and antifungal metabolites. PSM also support the growth of plants by improving the efficiency of biological nitrogen fixation besides synthesizing phytohormones. They stimulate the root and shoot growth, improve the root and shoot length, thereby enhance their biomass and also increases P uptake.

Mechanisms of P Solubilization

High amount of phosphorus constituting 95-99% are present in insoluble form bound to other elements like iron, aluminium and calcium. These are unavailable to plants for uptake, and so soils are found to be deficient in available phosphorus. Fortunately, there exists a group of microorganism whose job is to solubilize the insoluble phosphorus and release them into the soil solution. These microorganisms called as 'phosphorus solubilizing microorganism' releases or solubilize phosphate through various mode of actions. Phosphorus solubilizing activity by microbes is determined by their mechanism in lowering pH through production of different organic acids, chelation and mineralization (Fig.1). Thus, microorganisms have key role in the soil P cycle i.e. precipitation, sorption–desorption, and mineralization.

(i) Production of organic acids

The principal mechanism involved in solubilization of phosphates is the production of various low molecular weight organic acids such as oxalic, citric, lactic, gluconic, acetic, malic, succinic, tartaric, fumaric acids. The secretion of organic acids results in lowering of the soil pH which acidify the microbial cells and the surrounding creating an environment favorable for release of P bounded by ions. Another mechanism to production of organic acid is achieved through the release of H^+ ions to the outer surface in exchange for cation uptake or with the help of H^+ translocation ATPase. Among all the organic acids produced, it is reported that gluconic acid accounts for the most frequent released acid facilitating the solubilization of phosphorus. They chelate or substitute those cations which are bound to phosphorus and release it, thereby making it available to plant. There are also certain inorganic acids such as nitric, sulphuric, and carbonic whose production helps in phosphate solubilization. Their contribution and effectiveness, though, is much lower as compared to organic acids.

(ii) Liberation of enzymes

The second mechanism of microbial phosphate solubilization is the release of enzymes by microbes or by enzymolysis. Phosphate is solubilized to the solution by three groups of enzymes- non-specific phosphatases, phytases, and phosphonatases and C-P lyases. These enzymes play a vital role in mineralization and dissolution of P in the rhizosphere. They hydrolyze a wide range of organic P compounds in soil and releases P in available form for plant uptake. Non-specific phosphatases dephosphorylate phospho-ester or phosphor-anhydride bonds of organic matter. Based on the soil reaction, they could be acid (predominant in acid soils) and alkaline (abundant in alkaline) phosphomonoesterases, both of which are produced by phosphate solubilizing microorganisms. However, the relationship between phosphate solubilizers introduced into soil, phosphatase activity and the subsequent mineralization of phosphorus remains not fully explored and understood. The other enzyme phytases helps in release of P through the process of phytate degradation. Phytate is the primary source of organic form of phosphorus 'inositol', constituting about 35% of P stored in plant seeds and pollen., *(iii) Chelation*

Phosphorus solubilization is also carried out by chelation mechanism. The process involves the release of hydroxyl and carboxyl group of acids where they chelate other cations such as Fe, Al and Ca bounded to phosphate and dissolve P into the solution. When PSM are present they interact with other cations which are bound to P as Fe-P, Al-P and Ca-P, bind them to their site through chelation mediated process and freed the P, making them available to plants for utilization. Another such mechanism is the production of hydrogen sulphide (H_2S) which react with ferric sulphate to yield ferrous sulphate with the release of phosphate.

(iv) Mineralization

PSM species possess the ability to mineralize and solubilize phosphorus and make them accessible to plants. Generally, phosphorus is bound to aluminium and iron as Al-P and Fe-P in acid soils, whereas, in alkaline soil it is present as Ca-P. While these forms are unavailable to plant efforts are made to solubilize phosphate through the role of PSM. Microorganisms belonging to *Bacillus* and *Streptomyces* species have the potential to mineralize those complex organic phosphates mostly through the release of enzymes such as phosphoesterases, phytases and phospholipases.

Fig. 1 Different strains of PSM isolated from acid soils and their solubilizing capacity of phosphate with the clear halo form around the colonies in Pikovskaya's media

Use of Phosphate Solubilizing Microorganisms as Biofertilizers

Over the years several species of bacteria and fungi have been subjected to mass production and used successfully as a biofertilizers. Subsequently their usage also helps in improving the phosphorus use efficiency. Bacteria, most commonly belonging to genus *Pseudomonas fluorescens*, *P. putida*, *Bacillus* species and fungi group *Trichoderma viride*, arbuscular mycorhizal fungi are used as PSM biofertilizers. They can be used for all crops and upon their application PSM enhanced the growth, quality and overall yield of many crops upto 40%. Table 1 shows the effect of application of PSM bioformulation on soil and change in soil properties before sowing and after harvest of crop.

Table 1. Effect of PSM strains bio-formulation in maize plant for seed treatment and soil application in pot experiment before sowing and after harvest of crop

Sl. No.	Parameters	Time of analysis	pH	SOC (%)	Avail P (kg ha^{-1})	Total P (%)
1.	Seed treatment	Initial	4.95	0.42	7.02	0.38
		Final	4.0- 5.2	0.26- 1.58	3.71 - 14.33	0.20-1.60
2.	Soil application	Initial	5.05	0.45	7.32	0.39
		Final	4.1- 5.3	0.35-1.71	4.76-16.42	0.21-1.61

*SOC- soil organic carbon; Avail P- available phosphorus; Total P- total phosphorus

Species of PSM in Acid Soil

Microorganisms have their own diversity and niche depending on the soil reaction and the surrounding environment. Potential phosphate solubilizing microorganisms found in acid soils are *Trichoderma viride*, *Aspergillus* sp., *Penicillium* sp., *Actinomyces*, *Mucor*, *Rhizobium*, *Klebsiella*, *Enterobacter aerogenes*, *Citrobacter freundi*, *Azospirillum* sp., *Azotobacter chroococcum* and *Pseudomonas* sp.

Conclusion

There are considerable evidences pointing to the potential of PSM in enhancing the growth attributes and yield of many crops. Their efficiency, however, differs from strain to strain and from species to species depending upon the cultural and environmental conditions. The use of phosphate solubilizing microorganism as a microbial inoculants or biofertilizers serves a great purpose as alternative to chemical fertilizers besides acting as plant growth promoter and solubilising phosphate.

Reference

Jackson, M.L. (1973). Soil chemical analysis. Prince Hall of India (P) Limited, New Delhi, pp.103.

Khan, M.S., Zaidi, A., Ahemad, M., Oves, M. and Wani, P.A. (2010). Plant growth promotion by phosphate solubilizing fungi – current perspective. Archives of Agronomy and Soil Science, 56(1), 73-98.

Pikovskaya, R.I. (1948). Mobilization of phosphorus in soil in connection with vital activity of some microbial species. Microbiology, 17, 362-370.

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ROLE OF ARTIFICIAL INTELLIGENCE IN PLANT BREEDING

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Artificial Intelligence (AI) refers to the simulation of human intelligence in machines, allowing them to perform tasks that typically require human intelligence. These tasks include learning from experience, solving problems, recognizing patterns, understanding natural language and making decisions. Machine Learning (ML) develops algorithms that learn to perform specific tasks based on a provided data set. It is a subfield of artificial intelligence that is widely used in research and the industry. Supervised learning tasks aim to predict an output (either a discrete label, in the case of classification, or a numerical value, in the case of regression) for a given object, given a set of input features that describe the object. Supervised methods use labelled input data. Unsupervised methods do not use labels but find groups or trends in data (Van *et al*., 2021).

Plant breeding is the science and art of selecting and crossing plants with desirable traits to develop new plant varieties that are better suited for specific purposes, such as improving crop yields, disease resistance, tolerance to environmental stress and the overall quality of the plant. Artificial Intelligence (AI) refers to the simulation of human intelligence in machines, allowing them to perform tasks that typically require human intelligence. These tasks include learning from experience, solving problems, recognizing patterns, understanding natural language and making decisions.

The Role of Data in AI

- Training Data
- Supervised Learning
- Unsupervised Learning
- Reinforcement Learning
- Big Data
- Data Preprocessing
- Feature Engineering
- Bias and Fairness
- Data Augmentation
- Continuous Learning
- Data Security and Privacy
- Data Annotation

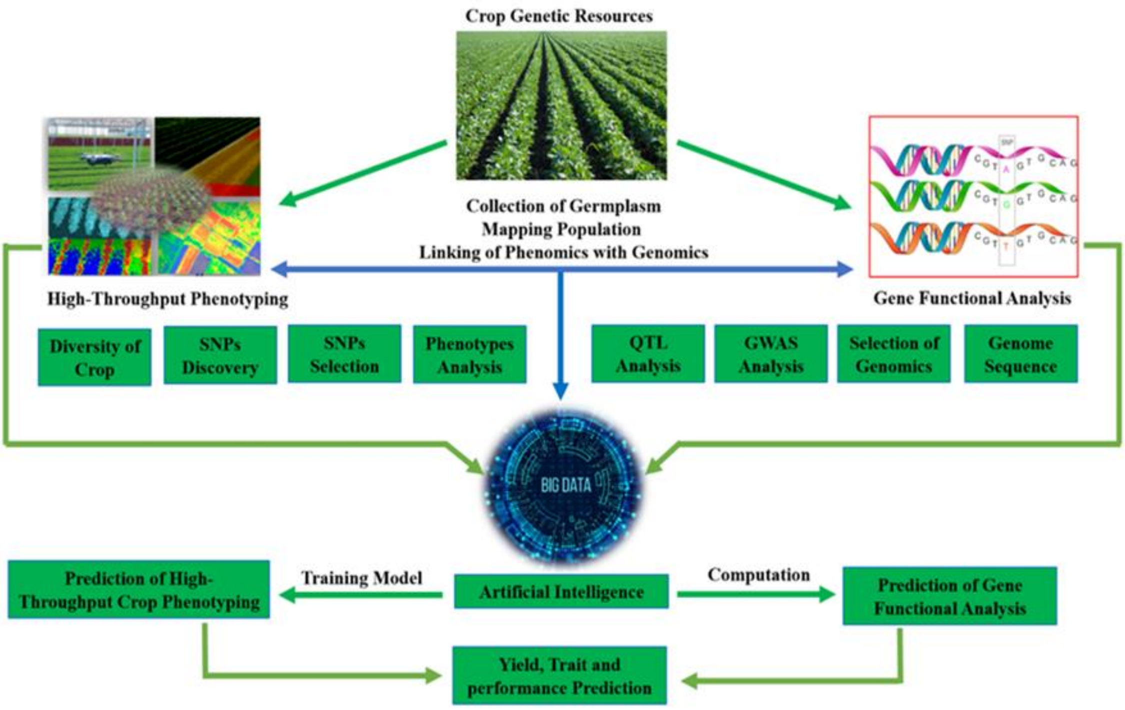
How AI is transforming Various Industries?

- Energy-Grid Management, Energy Consumption Optimization
- Agriculture-Precision Agriculture, Crop and Soil Monitoring
- Education-Personalized Learning, Automated Grading and Data Analytics
- Legal
- Entertainment
- Environmental Monitoring
- Public Safety
- Healthcare-Disease Diagnosis, Drug Discovery and Personalized Medicine
- Finance-Algorithmic Trading, Fraud Detection and Credit Scoring
- Retail-Recommendation Systems, Inventory Management, Chatbots and Virtual Assistants
- Manufacturing-Predictive Maintenance, Quality Control and Supply Chain Optimization

Applications of AI in Plant Breeding

Phenotyping and Trait Selection

- AI helps in automating the process of phenotyping, which involves measuring and analyzing plant characteristics.
- Computer vision and machine learning techniques can be used to assess traits such as leaf size, color, disease resistance and yield potential.



(Sampath *et al.*, 2023)

Genomic Selection

- AI algorithms can analyze genomic data to predict the performance of a plant based on its genetic markers.
- This allows breeders to select plants with desired traits more efficiently.

Optimization of Breeding Programs: AI can optimize breeding programs by suggesting mating schemes and selecting parental lines to maximize the probability of obtaining desirable offspring.

Disease and Pest Detection

- AI can be used for the early detection of diseases and pests in crops by analysing images and sensor data.
- This allows for timely intervention and disease management.

Climate Adaptation

- AI can help in developing crop varieties that are better suited to changing climate conditions.
- Machine learning models can predict how different genotypes will perform under various environmental scenarios.

Data Integration and Knowledge Discovery

- AI tools can integrate data from various sources, such as genomics, phenomics and environmental data, to identify relationships and patterns that can inform breeding decisions.

Crop Yield Prediction: Machine learning models can be used to predict crop yields based on historical data, weather conditions and other variables, helping breeders make informed decisions.

Genome Sequencing and Analysis

- AI can be used to improve the efficiency and accuracy of DNA sequencing processes.
- AI algorithms can help in base calling, error correction and assembly of DNA sequences, making the entire sequencing process faster and more reliable.

Data Collection and Preprocessing in Plant Breeding

Data Collection	Data Preprocessing
a. Image Analysis b. Drone Technology c. Sensor Networks d. Genomic Data	a. Data Cleaning b. Feature Extraction c. Normalization d. Data Integration e. Dimensionality Reduction

Predictive Modeling

a. Machine Learning:	b. Genomic Selection:
❖ AI models, particularly machine learning algorithms, can be used to develop predictive models that relate environmental conditions, genetics and other factors to plant traits. ❖ These models can help predict which plants are most likely to have desirable characteristics.	❖ AI can help identify markers in a plant's genetic code that are associated with specific traits. ❖ This is known as genomic selection and can significantly speed up the breeding process.

Decision Support Systems

- AI can assist breeders in making decisions by providing insights based on the data.
- For example, it can recommend which plants to crossbreed to achieve desired traits or which environmental conditions are ideal for specific varieties.

Automation

- In addition to data analysis, AI can be used for automating routine tasks in plant breeding, such as crossbreeding recommendations, selecting parent plants and data reporting.

Robustness and Adaptability

- AI models can adapt to changing environmental conditions and plant responses, making plant breeding more resilient to climate change and other uncertainties.

Data Sources in Plant Breeding

Field Trials	Genomic Data
❖ Phenotypic Data ❖ Environmental Data	❖ DNA Sequencing ❖ Single Nucleotide Polymorphism (SNP) Data

Herbaria and Germplasm Collections

Herbaria house preserved plant specimens and related information, providing a historical record of plant species. Germplasm collections contain diverse plant material, including seeds and genetic resources for breeding purposes.

Phenotyping Platforms

Automated phenotyping platforms use sensors and imaging technology to collect data on various plant traits, such as leaf area, canopy architecture, and disease symptoms. This technology provides high-throughput data collection in controlled environments.

Weather and Climate Data

Weather data, including historical climate records and forecasts, help plant breeders make informed decisions regarding planting times, crop management, and assessing the impact of climate change on crop performance.

Soil and Nutrient Data

Soil testing and nutrient analysis provide information about soil composition, pH, nutrient content, and fertility. This data helps breeders determine which plant varieties are best suited for specific soil types.

Biological Databases

Online databases and repositories, such as GenBank, provide access to genetic information, genome sequences, and related data for various plant species.

Remote Sensing Data

Satellite and drone imagery can provide valuable information about crop health, growth, and stress levels. These data sources are useful for monitoring large agricultural areas.

Historical and Ancestral Data

Historical records and ancestral information about plant varieties and breeding history can help breeders understand the lineage and genetic heritage of plants.

Farm Management Software

Modern farming involves the use of software applications for data collection and management. These systems may capture data related to crop performance, planting schedules, and inputs like fertilizers and pesticides.

Citizen Science

Crowd sourced data from farmers and gardening enthusiasts can provide valuable insights into how specific plant varieties perform in various regions and conditions.

Scientific Literature

Research papers, journals, and publications contain a wealth of information on plant genetics, breeding techniques, and the performance of different plant varieties.

Machine Learning Models in Plant Breeding

Random Forest is used for trait prediction, disease detection and feature selection in plant breeding.

Support Vector Machines (SVM) are used for classification tasks in plant breeding, such as identifying disease resistance or predicting crop yield.

Convolutional Neural Networks (CNN) are widely used for image - based plant disease detection and leaf segmentation.

Recurrent Neural Networks (RNN) can be used for time - series data analysis in plant breeding, such as predicting crop growth over time.

Bayesian Networks are used for modeling complex trait inheritance patterns and genetic analysis in plant breeding.

Genome - Wide Association Studies (GWAS) is a statistical approach used to identify associations between genetic markers and plant traits.

Deep Reinforcement Learning can be applied in optimizing crop management strategies and resource allocation.

Challenges in Plant Breeding with the use of AI

1. Data Quality and Bias
2. Data Privacy
3. Intellectual Property and Access
4. Regulatory Hurdles
5. Ethical AI Use
6. Validation and Testing
7. Resource Constraints

Ethical Considerations in Plant Breeding with the use of AI

1. Transparency
2. Equity and Inclusivity
3. Informed Consent
4. Environmental and Health Impact
5. Fair Access
6. Responsible Innovation
7. Accountability

Future Directions and Opportunities in Plant Breeding with the use of AI

1. Genome Editing and AI Integration
2. Predictive Breeding Models
3. Personalized Agriculture
4. AI-Powered Phenotyping Tools
5. AI for Climate Resilience
6. Quantum Computing for Genetic Analysis
7. AI and Plant Health Management
8. Global Collaboration
9. AI for Biodiversity Conservation
10. Responsible AI in Agriculture
11. AI-Driven Data Analytics
12. AI in Crop Monitoring and Forecasting
13. Education and Training

Conclusions

AI is a powerful tool in plant breeding that offers the potential to address the challenges of feeding a growing global population while adapting to changing environmental conditions. As the field continues to evolve, it is essential to emphasize responsible and ethical AI use to ensure that the benefits of AI in plant breeding are realized while safeguarding privacy, equity and sustainability. The future of plant breeding with AI is bright, with the potential to revolutionize agriculture and contribute to global food security.

References

Sampath, L., Venna S., Himakara Datta, M and Tushar, A.M. (2023) What is Artificial Intelligence in Plant Breeding. *Just Agriculture*. 3(11): 352-358.

Van Dijk, A.D.J., Kootstra, G., Kruijer, W and De Ridder, D. (2021) Machine learning in plant science and plant breeding. *Iscience*. 24(1): 1-12.

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ENTOMOPATHOGENIC BACTERIA: A POTENT BIOPESTICIDE FOR SUSTAINABLE AGRICULTURE

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The increasing use of chemicals in agriculture has given rise to concerns regarding public health, soil degradation, and environmental safety. To address these issues and ensure the consistent productivity of agricultural land, a sustainable approach is imperative. Pesticides, the primary chemical inputs in agriculture, pose significant risks. In response, microbial pesticides, derived from entomopathogenic microorganisms, offer promising alternatives. There are different entomopathogenic microbes such as fungi, nematodes, bacteria, protozoa and viruses. Bacteria are prokaryotic (without nucleus) single-celled organism and exist in communities of millions. Bacterial populations pathogenic to insect pests can cause major damage to the target insect population and are known as entomopathogenic bacteria (EPBs) (Lacey *et al.*, 2001). EPBs are mainly divided in two groups *i.e.*, endospore forming (e.g. genus *Bacillus*) and non-endospore forming (e.g. *Serratia* sp. and *Pseudomonas* sp.). The endospore forming bacteria are further divided into obligate and facultative pathogens. Families of bacteria having the properties of pathogenesis comprise bacillaceae, clostridiaceae, proteobacteria and actinobacteria. Their cosmopolitan nature and inherent versatility positions EPBs as promising alternatives for pest control in agriculture, aligning with the goals of sustainable and eco-friendly farming practices.

Bacterial Insect Pathogenesis

There are various modes and means for pathogenesis in insect by bacteria. There are three modes of entry: through the consumption of infected food, through a lesion and through vector. Mainly there are three types of infection *viz.*, bacteremia: multiplication in insect haemocoel; septicemia: bacteria invades the haemocoel, multiplies and produces toxins; toxaemia: bacteria that produces the toxin and usually confined to the gut lumen.

Bt *(Bacillus thuringiensis)*: *Bacillus thuringiensis*, aerobic, rod-shaped, motile, gram positive, endospore-forming bacterium, is one of the most successful microbial biopesticides. It produces crystal protein and delta-endotoxin, affecting very wide range of insect-pests (Gangwar *et al.*, 2021).

Gonza´lez-Cabrera *et al.* (2010) tested three commercial products of Bt against *Tuta absoluta* in tomato. In laboratory assay, Costar® (Bt var. *kurstaki*) showed least leaflet area damage. Costar® at concentration 45.2, 90.4 and 180.8 MIUl^{-1} showed low infested leaflets per plant in greenhouse and open field condition and low infested fruits in open field. In the open-field 90.4 and 180.8 MIU l^{-1} treatment gave similar highest non-injured yield.

Patel *et al.* (2020) from Anand reported that Bt strain of AAU was more effective than Bt strain of NBAIR for the management of *Spodoptera frugiperda* larvae of 2nd and 3rd instar under laboratory conditions.

Aarthi *et al.* (2022) evaluated different bioagents against 2nd instar larvae of *S. frugiperda* under laboratory conditions and found that Bt @ (3.5% ES) 2ml/l recorded higher mortality percentage than other treatments.

Wakde *et al.* (2022) concluded that per cent mortality increased with the increase in concentration after 96 hrs. of inoculation of Bt broth formulation in 3rd and 4th instar larvae of *Corcyra cephalonica* and *Galleria mellonella.*

EPBs other than Bt: This includes *Lysinibacillus sphaericus*, *Bacillus popillae*, *Serratia marcescens*, *Pseudomonas aeruginosa*, *Photorhabadus sp.* and *Xenorhabadus sp.* having different modes of infection. Among these bacterial entomopathogens some are discussed below.

***B. popillae*:** Spores of *B. popilliae* infect larvae (grubs) of Japanese beetles, eventually killing the larvae and preventing their development into adult beetles. They cause milky spores disease in grubs.

Shinde and Sharma (1971) conducted an experiment to assess the development of milky disease in inoculated grubs by injection method and soil inoculation method at two different doses against 1st, 2nd and 3rd instar white grubs of Japanese beetle (*Lachnosterna consanguinea*). In injection method, the higher dose 10^{6} spores/ grub shows high mortality, while soil inoculation at 4 × 10^9 spores/kg soil showed high mortality after 6 and 12 days but similar results after 18 days.

S. marcescens: The pathogenicity of *S. marcescens* is increased by the action of serralysin metalloproteinase. It allows bacteria to suppress cellular immunity by reducing the adhesion properties of immune surveillance cells in the insect hosts (Gangwar *et al.,* 2021).

***P. aeruginosa*: This ubiquitous bacterium infects insect larvae orally and determines extensive intestinal cell damage. Toxic compounds produced such as extracellular proteinases and metalloproteases are exported throughout the insect's body as a result of intestinal infection (Vacheron *et al.,* 2018).

Chin *et al.* (2021) observed the behavioral activities and mortality rate of *Coptotermis curvignathus* termite on wood block and in soil treated with different bacterial concentrations of *S. marcescens* and *P. aeruginosa.* They concluded that as the concentration increased the mortality rate increased and the percentage of weight loss of wood and soil decreased.

***Photorhabadus* sp**. and ***Xenorhabadus* sp:** Bacteria produce and spread various antimicrobial compounds to combat the growth of other microorganisms. They also release various enzymes that contribute to the degradation of haemocoel and make an ideal environment for the development of the nematode population (Gangwar *et al.,* 2021).

Adithya *et al.* (2020) compared 4 strains of *Photorhabdus luminescens*, 1 strain of *Xenorhabdus nematophila* and Bt in two different forms *viz.,* intact cell and cell supernatants against *Earias vitella* larvae. In both forms *X. nematophila* showed highest mortality followed by 4 strains of *P. luminescens* and least mortality was found in Bt.

Gümüssoy *et al.* (2022) observed that *Xenorhabdus bovienii* A54 cell-free supernatant exhibited high mortality rate against 5th instar larvae of *Cydia pomonella* in contact efficacy.

Unal *et al.* (2022) found that in cell suspension treatment of different *Xenorhabadus* and *Photorhabadus* against cutworm larvae, oral application showed better result than contact and highest mortality was recorded in *X. bovienii* KCS-45 in 1^{st} and 2^{nd} instar and *X. budapestensis* MGZ-4-5 in 3^{rd} and 4^{th} instar. They also conducted cell-free supernatants treatment of same species and strains against cutworm larvae where contact application performed better than oral application and *P. luminescens* subsp. k*ayaii* AV815 caused high mortality in 3^{rd} and 4^{th} instar.

Muhammad *et al.* (2022) exhibited that mortality of migratory locust was higher in cell-free filtrate than the bacterial suspension of *P. luminescens* (EGAP3). Both bacterial suspension and cell-free filtrate caused increasing mortality as concentration increased. During 7 days after treatment with cell-free filtrate showed higher results.

Yuksel *et al.* (2023) generated results against different larval instars of *Ephestia cautella* that contact application efficacy produced high mortality than oral. Cell-free supernatant caused higher mortality than cell suspension. In contact application, *X. nematophila* E76 strain showed higher mortality for all larval instar. In oral application, except for 3rd instar of cell suspension treatment, all instar in both treatments, *X. bovienii* MÇB-8 strain caused high mortality.

Genetically modified entomopathogenic bacteria (GM-EPBs): Genetic engineering has great potential for the development of new genetically modified entomopathogens. These GM-EPBs are developed to achieve more resistance to adverse environmental factors, higher pathogenicity, lower spraying requirements and long-term persistence of entomopathogenic bacteria (Azizoglu *et al.*, 2020).

Conclusion

In conclusion, the transition to sustainable agricultural practices is paramount for safeguarding public health, preserving soil integrity, and ensuring environmental safety. Embracing microbial pesticides, with a focus on entomopathogenic microorganisms, presents a viable solution to mitigate the adverse effects associated with conventional chemical inputs in agriculture.

References

Aarthi Helen, P.; Tamboli, N. D., & More, S. A. (2022). Bioefficacy of bio-control agents against eggs, larvae and pupa of fall armyworm *Spodoptera frugiperda* (JE Smith) on maize under laboratory conditions. *Pharma innov*., 11(4): 461-464

Adithya, S.; Shivaprakash, M. and Sowmya, E. (2020). Evaluation of insecticidal activity of entomopathogenic bacteria *Photorhabdus* and *Xenorhabdus* against shoot and fruit borer *Earias vittella* (Lepidoptera: Noctuidae) of vegetable crops. *J. Èntomol. Zoöl. Stud*, 8, 2343-2348.

Azizoglu, U.; Jouzani, G. S.; Yilmaz, N.; Baz, E. and Ozkok, D. (2020). Genetically modified entomopathogenic bacteria, recent developments, benefits and impacts: A review. *Sci. Total Environ.*, 734, 139169.

Chin, K. L.; H'ng, P. S.; Lee, C. L.; Wong, W. Z.; Go, W. Z.; Khoo, P. S.; Luqman, A. C. and Ashaari, Z. (2021). Application strategies by selective medium treated with entomopathogenic bacteria *Serratia marcescens* and *Pseudomonas aeruginosa* as potential biocontrol against *Coptotermes curvignathus*. *R. Soc. Open Sci.*, 8(4), 201311.

Gangwar, P.; Trivedi, M.; and Rajesh, K. (2021). Entomopathogenic Bacteria: In "*Microbial Approaches for Insect Pest Management*."(Omkar, T.). Springer, pp: 59-79

González-Cabrera, J.; Mollá, O.; Montón, H., and Urbaneja, A. (2011). Efficacy of *Bacillus thuringiensis* (Berliner) in controlling the tomato borer, *Tuta absoluta* (Meyrick)(Lepidoptera: Gelechiidae). *BioControl*, 56, 71-80.

Gümüşsoy, A.; Yüksel, E.; Özer, G.; İmren, M.; Canhilal, R.; Amer, M. & Dababat, A. A. (2022). Identification and biocontrol potential of entomopathogenic nematodes and their endosymbiotic bacteria in apple orchards against the codling moth, *Cydia pomonella* (L.)(Lepidoptera: Tortricidae). *Insects*, 13(12), 1085.

Lacey, L.A.; Frutos, R.; Kaya, H. K. and Vail, P. (2001). "Insect pathogens as biological control agents: do they have a future?." *Biol. Control.*, 21(3) :230–248

Muhammad, J.; Fathy, Z. and Moussa, S. (2022). Entomopathogenic bacteria *Photorhabdus luminescens* as natural enemy against the African migratory locust, *Locusta migratoria migratorioides* (Reiche & Fairmaire, 1849) (Orthoptera: Acrididae). *Egypt. J. Biol. Pest Control*, 32(1), 92.

Patel, P. H.; Sisodiya, D. B.; Raghunandan, B. L.; Patel, N. B.; Gohel, V. R. and Chavada, K. M. (2020). Bio-efficacy of entomopathogenic fungi and bacteria against invasive pest *Spodoptera frugiperda* (JE Smith) under laboratory condition. *J. Entomol. Zool.*, 8(6), 716-720.

Shinde, V. K. R. and Sharma, S. K. (1971). Bacillus popilliae Pathogenic to *Lachnosterna consanguinea*. *J. Econ. Entomol.*, 64(5), 1301-1302.

Ünal, M.; Yüksel, E. and Canhilal, R. (2022). Biocontrol potential of cell suspensions and cell-free superntants of different *Xenorhabdus* and *Photorhabdus* bacteria against the different larval instars of *Agrotis ipsilon* (Hufnagel)(Lepidoptera: Noctuidae). *Exp. Parasitol.*, 242, 108394.

Vacheron, J.; Péchy-Tarr, M.; Brochet, S.; Heiman, C. M.; Stojiljkovic, M.; Maurhofer, M. and Keel, C. (2019). T6SS contributes to gut microbiome invasion and killing of an herbivorous pest insect by plant-beneficial *Pseudomonas protegens*. *The ISME journal*, 13(5), 1318-1329.

Wakde, S.; Tomar, R. K. S.; Awasthi, A. K.; Nirmalkar, V.; Tiwari, R. K. S. and Kerketta, A. (2022). Bioefficacy of *Bacillus thuringiensis* against different instars of laboratory insects rice moth (*Corcyra cephalonica*) and greater wax moth (*Galleria mellonella*). *Mortality*, 10, 100.

Yüksel, E.; Ormanoğlu, N.; İmren, M. and Canhilal, R. (2023). Assessment of biocontrol potential of different *Steinernema* species and their bacterial symbionts, *Xenorhabdus* species against larvae of almond moth, *Ephestia cautella* (Walker). *J. Stored Prod. Res.*, 101, 102082.

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FOOT AND MOUTH DISEASE: THE HIDDEN EPIDEMIC IN ANIMAL KINGDOM

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Foot and Mouth Disease (FMD), often abbreviated as FMD, is a highly contagious viral illness that affects a broad spectrum of cloven-hoofed animals, including cattle, pigs, sheep, and goats. Although less well-known than some of its counterparts, like avian flu or mad cow disease, FMD has the ability to ruin farms, sabotage food supply networks, and affect the lives of countless people. Caused by an aphthovirus belonging to the Picornaviridae family, FMD is known to have seven serotypes: A, O, C, Asia, and SAT (Southern African Territories), each with additional variation among the strains.

The history of Foot and Mouth Disease dates back centuries, with documented outbreaks causing considerable economic and social distress. Its name is derived from the typical symptoms it produces, including blisters and painful sores on the mouth, feet, and occasionally the udders. The impact of FMD, however, goes far beyond mere discomfort, sending shockwaves through farming communities and inciting fear in agronomists, veterinarians, and policymakers. Morbidity in a vulnerable population can reach 100%, with rare fatalities occurring only in young animals. While FMD is present everywhere, it has been completely eradicated in some areas, such as North America and Europe. Without stringent measures, FMD can be easily reintroduced into disease-free areas, posing a financial burden on the international livestock trade in endemic countries.

Symptoms of FMD

Numerous clinical symptoms, varying in intensity, are indicative of the illness. Although FMD usually does not result in death for adult animals, it can have serious consequences for both animal welfare and the economy. Clinical signs include fever, vesicles (fluid-filled blisters) in the mouth, interdigital spaces, teats, and coronary bands, excessive salivation, lameness, reduced feed intake, weight loss, and drooling. Decreased milk production may occur in dairy cattle. Secondary bacterial infections are also common due to open sores, and even after recovery, animals can harbor the virus, causing new outbreaks.

Transmission and Spread of FMD

Animals can become infected through inhalation of virus particles in the air or ingestion of virus particles. All of the excretions and secretions from infected animals contain FMD. Transmission can occur through saliva, milk, semen, contaminated pens, buildings, vehicles, materials, clothes, shoes, equipment, aerosols, and even through feeding raw or improperly cooked meat or animal products. Even after recovery, animals can harbor the virus, causing new outbreaks.

Significances: How Important is FMD?

Foot-and-Mouth Disease (FMD) is a highly contagious viral disease with significant implications for both the livestock industry and international trade.

- It poses economic impacts, jeopardizes food security, risks livelihoods, compromises animal welfare, and disrupts global trade.
- Trade restrictions imposed during outbreaks can result in substantial financial losses for ranchers, farmers, and countries overall.
- Food shortages and price increases may arise from the disease's potential to force the culling of diseased animals, impacting the accessibility and cost of necessary protein sources for human nutrition.
- Livestock farming, a major income source for many, particularly in rural areas, is at risk due to lowered animal productivity and market value.
- The suffering experienced by animals further underscores the significance of treating FMD. Since FMD is a transboundary illness, it can easily move across national boundaries, prompting nations to impose trade restrictions and quarantine measures.

These measures impact not only the livestock industry but also the stability of the world economy.

Prevention and Control Measures

The implementation of the FMD control strategy varies, but good biosecurity procedures are crucial.

- At the farm level, measures include restricting public access, managing the addition of new animals, routine cleaning and disinfecting, illness monitoring and reporting, and proper disposal of manure and dead cattle.
- Contingency planning for outbreaks involves eliminating contact animals, proper carcass and animal product disposal, monitoring and tracking infected or exposed livestock, enforcing quarantine regulations, and thorough disinfection.

Use of Vaccination

Depending on the FMD situation, vaccination campaigns must cover 80% or more of the target population quickly. Timing should account for maternal immunity, and vaccines must be safe, effective, and antigenically match the field strains according to WOAH standards. While vaccination may be part of a successful control strategy, national authorities decide whether to employ it.

Conclusion

Foot and Mouth Disease poses multifaceted challenges, requiring a comprehensive approach to mitigate its impact. Addressing economic, food security, livelihood, and animal welfare concerns, while implementing stringent prevention and control measures, is crucial for a global response to this significant threat.

References

Food and Agriculture Organization. (n.d.). *Introduction to foot and mouth disease* [Slide show]. FAO elearning Academy. https://elearning.fao.org/course/view.php?id=902

Chakraborty, S., Kumar, N., Dhama, K., Verma, A. K., Tiwari, R., Kumar, A., & Singh, S. V. (2014). Foot-and-mouth disease, an economically important disease of animals. *Advances in Animal and Veterinary Sciences*, 2(25), 1-18.

Singh, B., Prasad, S., Sinha, D. K., & Verma, M. R. (2013). Estimation of economic losses due to foot and mouth disease in India. *Indian J. Anim. Sci*, 83(9), 964-970.

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EDIBLE PACKAGING: A SUSTAINABLE FOOD FUTURE

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Food packaging plays a critical role in the food industry's ultimate preparation process and is an essential link in the food supply chain. Its essential function in society is to safeguard food from deterioration and damage, maintain safety and hygienic conditions, and aggressively minimize food waste. Nevertheless, spoiling causes more than 30% of food to be lost, adding to the world's solid waste problem, which is expected to reach 2.2 billion tons yearly by 2025. Conventional packaging exacerbates environmental problems by causing pollution and dependency on petroleum reserves. It is frequently non-biodegradable and made of non-renewable resources like plastic. The effects on the environment highlight the necessity of sustainable food packaging alternatives in order to solve waste and pollution issues in the sector.

Growing customer expectations for natural, premium, and sustainable goods have resulted in a change in emphasis toward the development of eco-friendly packaging amid environmental concerns. Reducing environmental effect can be achieved by using components including proteins, lipids, chitosan, starches, and cellulose derivatives in edible packaging. With a predicted CAGR of 7.64% from 2021 to 2027, the worldwide market, estimated at USD 2.06 billion in 2020, reflects this move toward environmental consciousness. The increase in popularity of edible films and coatings as environmentally friendly substitutes for traditional plastic packaging is the reason for the expansion. Benefits of this packaging include biocompatibility, simple decomposition, non-toxicity, and gas and moisture barrier qualities. The potential of edible packaging to lower waste in landfills, lower pollution, and help mitigate climate change is substantial, despite obstacles including limited resistance to gases and liquids and the requirement for industrial-scale manufacture. The food industry's attitude to sustainability might undergo a radical change as research on edible packaging advances.

Edible Packaging

Foods have been protected and moisture loss prevented for centuries by the use of edible coatings, which have their origins in China in the 12th century and subsequently in England. As these coatings developed throughout time, they were used in the 20th century to make chocolate and other sweet coatings for confections, improve the sheen on fruits and vegetables, and stop water loss. The historical relevance of these items emphasizes their ongoing contribution to the preservation and enhancement of different food products' attractiveness.

When it comes to active food packaging, edible packaging is unique since it is biodegradable and sustainable while yet providing better food-quality optimization than conventional packaging techniques. Food quality preservation, shelf life extension, waste reduction, and improved cost-effectiveness of packaging materials are among its uses. Sophisticated and adaptable, edible films are made of different materials and may be used as vehicles for active ingredients such as antimicrobials and antioxidants. They represent a significant advancement in the field of food science. This subject has a lot of promise, as seen by the rise in research activity over the last 10 years.

A thin, continuous layer of edible substance created on, deposited on, or between foods or food components is known as an edible film or coating. In order to improve the shelf life and quality of food products, edible packaging is available in a variety of forms, such as composite edible packaging, smart/intelligent and active packaging, nanopackaging, and nanoformulations. Edible packaging is an essential component that protects food from mechanical, chemical, physical, and microbiological hazards. In order to maintain the best possible preservation and food quality, it serves as a protective barrier, blocking oxidation, water penetration, and unwanted enzyme activation. Edible ingredients, mostly natural polymers that are safe for human consumption, are the source of the materials utilized in edible packaging. These substances may be processed to create films and coatings of varying densities. Films are used for wraps, pouches, bags, capsules, and casings, whilst coatings become an integral component of the food product and are not intended for removal. A food product's individual composition, processing techniques, and material choice all influence the edible packaging components used. It's critical that the meal be compatible with the senses. Though progress has been made, questions remain about how to safely and effectively scale up edible food packaging on an industrial scale.

Forms of Edible Packaging

Edible coating: Food surfaces are directly coated with edible materials in the form of liquid suspension, emulsion, or powder. A diffusion-based adhesion procedure is used in the application to guarantee a smooth transition between the coating solution and the food product's surface. These coatings are applied using a variety of techniques, including as dipping, spraying, brushing, fluidized bed processing, and the panning technique. Foods are submerged in the coating solution while using the dipping technique, whereas the spraying technique applies the coating uniformly. Food products are coated with a stream of air in fluidized bed processing, whereas brushing allows for more accurate coating application. Food products are tumbled with the coating solution in a rotating drum using the panning process. These application methods highlight the adaptability of edible coatings in the food business by improving food quality, shelf life, and aesthetic appeal.

Edible films: Typically, edible ingredients are dissolved in solvent combinations, water, or alcohol to create edible films. Plasticizers are added to the matrix material to improve its mechanical qualities, which increase its durability and flexibility. Additional ingredients, such colors, flavorings, and antimicrobial agents, are added in accordance with the needs of the edible material for the purpose for which it is designed. The surface characteristics of the intended food product, such as wettability, contact angle, and surface tension, have a significant impact on the choice of edible packaging solution and application technique.

The ways that coatings and edible films are applied differ from one another. Using techniques like lamination or multilayering, edible films are created as solid sheets that are then applied to food products. Edible coatings, on the other hand, are applied directly to the surface of food in liquid form. To maximize the use of edible packaging in the food sector and make sure that the technique used is in line with the unique requirements and features of the food product being packaged, it is imperative to comprehend these subtle variances.

Materials for Edible Packaging

Edible packaging utilizes a variety of materials derived from natural sources, providing sustainable alternatives to traditional packaging. The key materials used for edible packaging include:

- **Protein:** Keratin, egg white protein, rice bran protein, soy protein, collagen, cottonseed protein, peanut protein, corn zein, wheat gluten, fish myofibrillar protein, sorghum protein, gelatine, and casein.
- **Polysaccharides:** Pectin, chitosan, gum, alginate, carrageenan, xanthan gum, modified cellulose (CMC, MC, HPC, HPMC), modified starch, and modified starch modified cellulose.
- **Lipids:** Acetoglycerides, shellac, terpene, and waxes such as candelilla, rice bran, paraffin, carnauba, and beeswax.
- **Composite:** Emulsion and bi-layer composite films.
- **Plasticizers:** Water, polyethylene glycol, glycerine, sorbitol, sugar, and propylene glycol.
- Functional additions include tastes, colours, nutrients, antioxidants, antimicrobials, and nutraceuticals.
- **Additional ingredients:** lipid emulsions (fatty acids, edible waxes), emulsifiers (lecithin, tweens, spans).

These substances are picked because they can produce films or coatings that are appropriate for a variety of food items, are safe to eat, and biodegrade. The choice is frequently based on the intended properties of the edible packaging as well as the particular specifications of the packaged food.

Characteristics of Edible Packaging

Many elements are important to achieve the desired qualities in films, coatings, and edible packaging. Physical, chemical, mechanical, thermal, barrier, and biological properties are all included in this. Moisture/gas barrier, rheological, adhesive characteristics, transparency, solubility, mechanical strength, color, and antibacterial qualities are some of the important attributes. Polymer type and crystallinity, formulation parameters, solvent selection, and additive concentrations are a few examples of influencing variables. The quality of the packaging system is also greatly impacted by the surface qualities and attributes of the food item, as well as the deposition techniques used. The efficiency and applicability of edible coatings and films in preserving and improving food items are determined by the complex interactions among these variables.

Advantages of Edible Packaging

Edible packaging offers a range of benefits, making it a compelling choice in the pursuit of sustainable and innovative packaging solutions. The key attributes that contribute to its increasing popularity in the food industry include:

- Environmentally friendly, recyclable, and entirely eaten or biodegradable.
- Boosts the qualities of organoleptic features, such as colour and sweetness.
- Through supplementation, nutritional qualities are improved.
- Delay the climacteric fruits' ripening period.
- It is feasible to package fruits like strawberries individually.
- Movies can function as carriers of antioxidant or antimicrobial compounds.
- One use for film is the microencapsulation of flavouring compounds.
- Food waste may be minimized by using edible packaging to increase the shelf life of food items and decrease the chance of deterioration.
- Food-grade films and coatings offer a safeguard against environmental elements including moisture and oxidation, which can help maintain and improve the quality of food items.

Limitations of Edible Packaging

- The cost of the new wraps is higher than that of synthetic packaging. The developer thinks that the benefits to the ecology and nutrition, however, will outweigh the higher price.
- During food distribution and storage, they would be utilized to wrap food items within an additional synthetic packaging.
- Deficient mechanical characteristics.

Applications of Edible Packaging

Fresh-cut fruits and vegetables, meat, cereals, nuts, cheese, baked goods, and confections are among the food categories for which edible packaging appears to be a feasible option. Effective uses demonstrate how versatile it is, with the type of food, how long it will be stored, and other factors influencing the edible packaging option. With its flexible and ecological packaging solution, this invention meets a range of needs in the food sector.

Regulations

Food-grade packaging, which comes in the same categories as packaging materials and food contact substances, is an important part of food products. Following food laws is essential, since they demand the use of FDA-approved or generally recognized as safe (GRAS) substances. When using edible packaging materials and additives, adherence to Good Manufacturing Practices (GMP) is crucial. Common ingredients include proteins from wheat, peanuts, soy, fish, eggs, and milk. As a result, allergy labeling regulations, such as the Food allergy Labelling and Consumer Protection Act of 2004, must be followed.

Conclusion

In conclusion, the food sector has made great progress toward sustainable and consumer-friendly alternatives with the rise in interest in and innovation around edible packaging. Promising benefits associated with the use of biopolymers include biodegradability, ease of processing, and compatibility with human health. Nutraceuticals and plant extracts are examples of additives that not only improve the functional performance of packaging but may also offer possible health advantages to customers. Subsequent research endeavours have to concentrate on honing coating technologies, enhancing bio-based material compositions, and tackling issues associated with the potential hazards of human ingestion. As edible packaging continues to develop, there is potential for intelligent design solutions where active, intelligent, and sustainable characteristics come together to provide improved product quality and safety in the changing food packaging market.

References

Cerqueira, M.A.P.R., Pereira, R.N.C., da Silva Ramos, O.L., Teixeira, J.A.C. and Vicente, A.A. eds. (2017). Edible food packaging: materials and processing technologies.

Chhikara, S. and Kumar, D. (2022). Edible coating and edible film as food packaging material: A review. *Journal of Packaging Technology and Research*, 6(1), 1-10.

Kumar, A., Hasan, M., Mangaraj, S., Pravitha, M., Verma, D.K. and Srivastav, P.P. (2022). Trends in edible packaging films and its prospective future in food: a review. *Applied Food Research*, 2(1), 100118.

Kumar, N., Pratibha, Prasad, J., Yadav, A., Upadhyay, A., Neeraj, Shukla, S., Petkoska, A.T., Heena, Suri, S. and Gniewosz, M. (2023). Recent Trends in Edible Packaging for

Food Applications - Perspective for the Future. *Food Engineering Reviews*, 15(4), 718-747.

Petkoska, A.T., Daniloski, D., D'Cunha, N.M., Naumovski, N. and Broach, A.T. (2021). Edible packaging: Sustainable solutions and novel trends in food packaging. *Food Research International*, 140, 109981.

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ROLE OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING FOR SMART DECISION SUPPORT SYSTEMS IN AGRICULTURE

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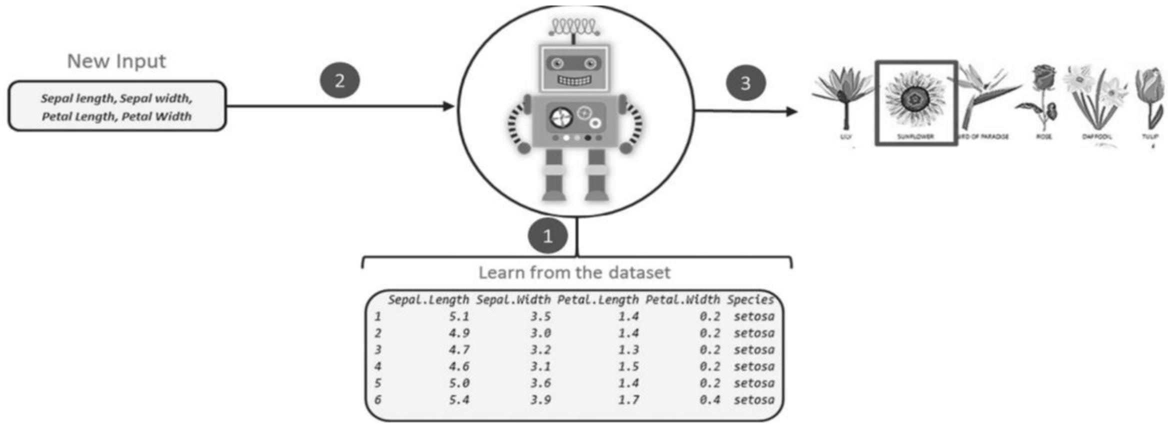
The current population of the world is 7.8 billion and is expected to reach 9.8 billion by 2050. Today's biggest challenge is feeding the world's growing population with limited land and a high demand for food production, particularly in developing nations. Numerous difficulties have arisen in the field of agriculture as a result of the pressing need to produce more crops on less land. A vicious cycle of farming-related global warming and climate change-related agricultural yield reduction has emerged. The environment and public health have suffered as a result of farms using excessive amounts of chemicals to improve soil fertility and control weeds and pests. Natural resources needed for agriculture, such as phosphorous and energy, are scarce. Limited water resources and a rise in plant illnesses.

Artificial Intelligence (AI) has emerged as a transformative force, reshaping the landscape of farming and cultivation. As we stand at the nexus of technology and tradition, the integration of AI in agriculture heralds a new era—one where algorithms and data converge with the age-old rhythms of the land. Utilizing digital technologies to gather, store, and further analyze electronic agricultural data in order to improve reasoning and decision-making through artificial intelligence (AI) approaches is known as "digital agriculture. "One such method is precision agriculture, which keeps an eye on temperature, humidity, and soil moisture and composition in order to optimize water and fertilizer needs for various farm areas and crops. Additionally, there are methods for detecting diseases and deficiencies in plants using computer vision and machine learning. One such technique is the recognition of weeds, which makes it possible to spray only the areas of a field where weeds or diseased plants are present, rather than the entire field. AI use in agriculture is assisting in the development of farming practices that can boost crop yield and lessen the difficulties mentioned earlier.

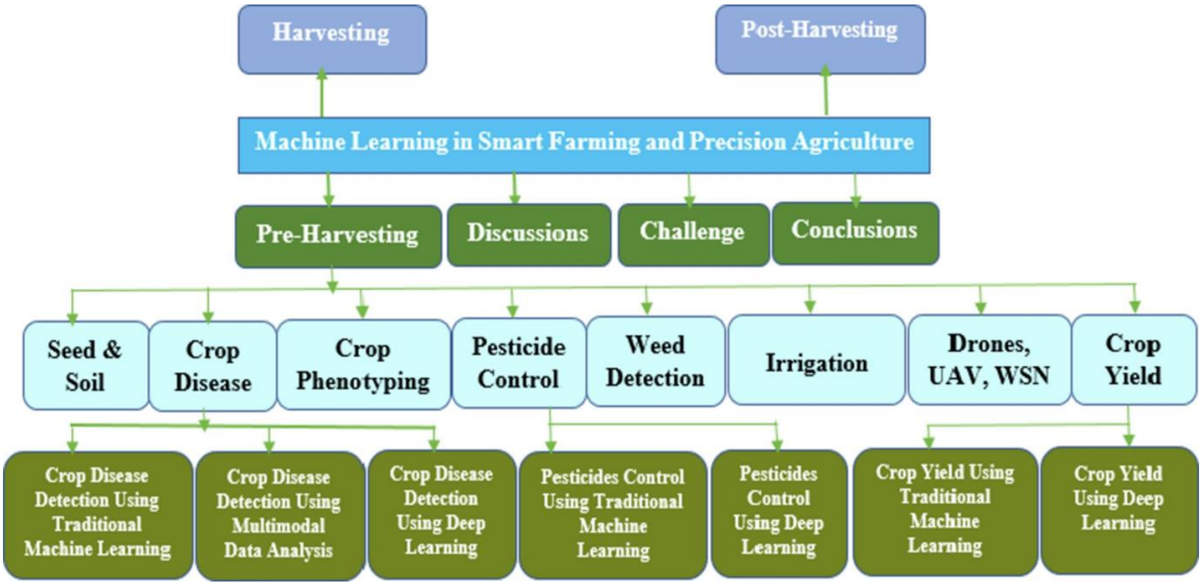
Machine learning (ML) plays a crucial role in smart farming. Machine learning enables the computers to learn without being explicitly programmed. Machine learning algorithms use computational methods to learn information directly from the data without relying on a predetermined equation as model. ML is applied to crop management and selection. For instance, different crops require different types of soil to grow. Farmers must carefully select the best land for their crops based on the production potential. Machine learning classification algorithms can be used to determine if the land is suitable for a given crop. The required level of water resources can be ascertained using a machine learning regression algorithm.



Smart Decision Support Systems (DSS) in agriculture represent a technological evolution that harnesses the power of data-driven insights to empower farmers and stakeholders in making informed decisions. These systems integrate advanced technologies, such as Artificial Intelligence (AI), Machine Learning (ML), and data analytics, to provide comprehensive and timely information for optimizing various aspects of agricultural operations. The primary goal of Smart DSS in agriculture is to enhance efficiency, productivity, and sustainability. These systems leverage real-time data from diverse sources, including sensors, satellite imagery, weather stations, and historical records, to offer a holistic view of the farm ecosystem. By processing this wealth of information, Smart DSS assists farmers in tasks such as crop management, resource allocation, and risk mitigation.

Applications of AI and Machine learning in Agriculture

AI and machine learning analyze data from various sources, including satellites, sensors, and weather stations, to provide farmers with precise insights into crop health, soil conditions, and weather patterns. This information enables targeted and optimized resource management, including irrigation, fertilization, and pest control.



Predicting Tomorrow's Harvest: Crop Yield Prediction and Price Forecasting

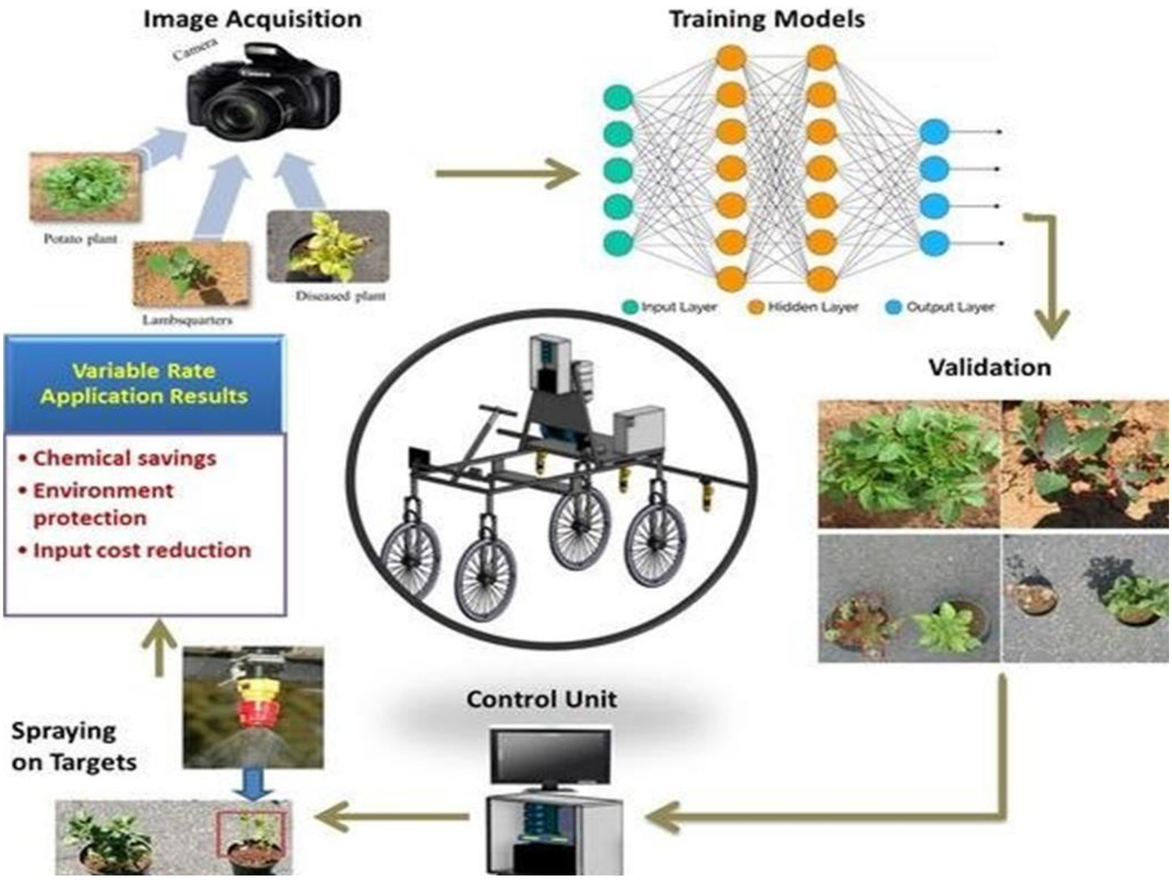
The integration of Artificial Intelligence (AI) and Machine Learning (ML) in agriculture has revolutionized crop yield prediction and price forecasting. Through the meticulous analysis of historical yield data, weather patterns, and market trends, AI and ML algorithms empower farmers with valuable insights. This enables strategic decision-making regarding crop selection, planting schedules, and resource allocation, thereby mitigating risks associated with fluctuating market prices. By synthesizing historical data with real-time information on soil conditions, weather forecasts, and agronomic practices, AI algorithms develop models that forecast the potential yield of crops. This insight empowers farmers with the ability to plan their agricultural activities meticulously, from planting schedules to harvest timelines, optimizing their resources for maximum efficiency. Beyond the intricacies of the field, the predictive power extends to the economic aspect of agriculture through Price Forecasting. AI and ML models ingest market data, historical pricing trends, and global economic indicators to anticipate future prices for agricultural commodities.

Crop and Soil Health Monitoring

AI and ML technologies have brought about a paradigm shift in the monitoring of crop and soil health. Leveraging sensor networks, satellite imagery, and unmanned aerial vehicles equipped with advanced sensors, farmers gain real-time insights into the well-being of their crops and the conditions of the soil. This precision farming approach allows for targeted interventions, optimizing the use of fertilizers and pesticides and ensuring early detection of nutrient deficiencies, pest infestations, or diseases.

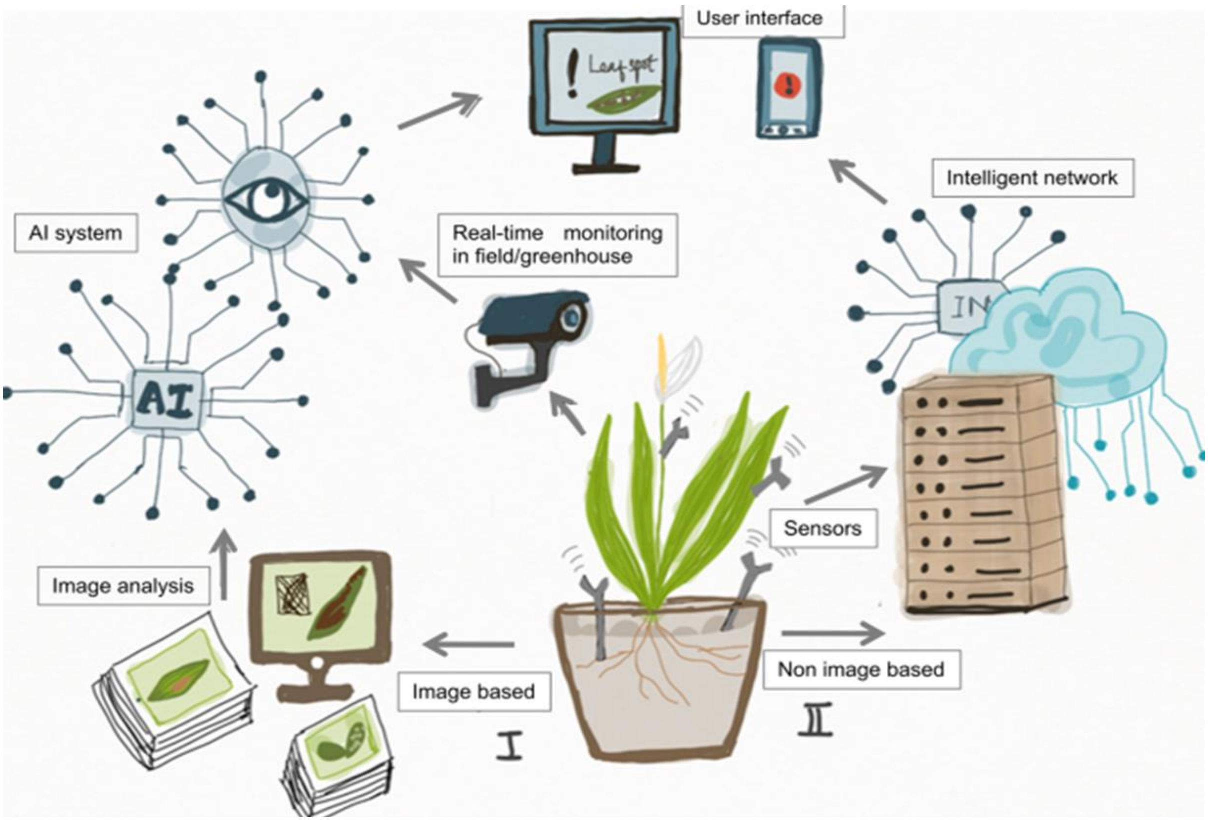
Intelligent Spraying

In the realm of pest and disease management, intelligent spraying systems guided by AI algorithms offer a transformative solution. By analyzing data from sensors and cameras, these systems identify areas with high pest density or disease outbreaks and helps in preparing the pesticide map. This information directs precision spraying through Variable rate applicator and minimizes overall pesticide use. The result is not only a reduction in environmental impact but also increased cost-efficiency for farmers through targeted resource utilization.



Guardians of the Harvest: Disease Detection and Management

AI and ML play a pivotal role in disease diagnosis, providing farmers with a powerful tool to combat agricultural ailments. Machine Learning models, trained on extensive datasets featuring images of healthy and diseased crops, can accurately identify patterns associated with various diseases. This facilitates early warning systems and equips farmers with prescriptive actions, contributing to disease prevention and the preservation of crop health. For the assessment of crop health, machine learning (ML) can be used in conjunction with analysis software. Farmers are able to target the application of pesticides in those particular areas by using the data to identify which infestation areas are most critical. Customizing the environment can have a big impact. One such instance is the German start-up Plantix, which develops an app that uses machine learning and image recognition to detect plant diseases and nutrients. Through the use of computer-aided systems, diseases can be effectively diagnosed and control measures implemented. A model utilizing fuzzy logic has been created to predict diseases by taking into account the duration of leaf wetness. pre-processing of a leaf image segment to separate the diseased portion from the non-diseased portion and the background. The damaged portion was then cropped and sent to distant labs for additional diagnosis. With image processing, pest identification and nutrient deficiency recognition are also possible.



Nurturing the Roots: Smart Irrigation Systems

AI is capable of much more than just raising crop yields and cutting production costs. An irrigation system's automation control can be improved by utilizing AI-based agriculture systems that make use of a variety of data sets, including satellite imagery, temperature, humidity, climate, and weather forecasts. This will help farmers make the best decisions possible regarding water management so they can conserve energy and optimize water uses. Evapotranspiration, a water cycle that includes transpiration as well as evaporation, has long been a crucial factor in designing irrigation systems tailored to individual crops. Without requiring site-specific calibration, farmers can now estimate and evaluate daily rainfall and potential evapotranspiration more accurately thanks to modern satellite imagery, weather forecasts, and remote sensing. weather sensors paired with location information from a GIS-based system can generate a water requirement map for scheduling irrigation.

The Autonomous Agriculturist: Agriculture Robots

Robotic technology in agriculture has for various operations like seeding, planting, weeding, harvesting and post-harvest operations. The advent of AI and ML in agriculture is embodied by intelligent agriculture robots. These autonomous entities, equipped with advanced capabilities, undertake a spectrum of tasks from planting and harvesting to weeding and monitoring. Using sensors and cameras, these robots navigate fields, collecting valuable data for decision-making. The automation of repetitive tasks not only addresses labor efficiency concerns but also ensures continuous monitoring, offering real-time data collection for better decision support.

Challenges in the Adoption of AI in Agriculture

Despite the enormous potential that artificial intelligence offers for applications in agriculture, most farms in the nation are still unfamiliar with reliable high-tech technological solutions. There are many unknown external variables that farmers are exposed to, such as the presence of pests and the weather. Planning at the beginning of harvesting might not be the best idea due to shifting outside factors. For AI systems to train machines and generate accurate predictions, a large amount of data is required. Large agricultural lands make it difficult to obtain temporal data due to certain well-defined constraints, even though spatial data can be obtained with ease. Additionally, the cost of implementing AI in agriculture is rising in India.

Conclusion

The benefits of AI in agriculture are undeniable as it contributes significantly to agriculture through controlled and automatic farm activities like- Irrigation, pest management, soil, and crop monitoring. Data generated by various sensors are managed and analyzed by using machine learning and deep learning based approaches to develop smart decision support systems. AI can assist farmers in raising their production capacity while lowering labor costs and drudgery. It goes without saying that the widespread use of AI in all application areas will lead to a perfect transformation in the way we currently conduct agricultural research and development. AI is moving toward more accurate and automated real-time management, which is assisting in the standardization of traditional agriculture into low-cost, precision agriculture. The farming community must be able to use and access the AI solution. AI solutions should provide an open source platform by lowering the cost of their solutions in order to encourage quicker adoption and deeper understanding among farmers.

References

Misra, N. N., Dixit, Y., Al-Mallahi, A., Bhullar, M. S., Upadhyay, R., & Martynenko, A. (2020). IoT, big data, and artificial intelligence in agriculture and food industry. IEEE Internet of things Journal, 9(9), 6305-6324.

Montas, H. and Madramootoo, C. A. (1992). A Decision Support System for Soil Conservation Planning. Computers and Electronics in Agriculture, 7(3), 187-202.

Munirah, M. Y., Rozlini, M. and Siti, Y. M. "An Expert System Development: Its Application on Diagnosing Oyster Mushroom Diseases", 13th International Conference on Control, Automation and Systems, Gwangju, South Korea, October 20-23, 2013.

Papageorgiou, E. I., Markinos, A. T. and Gemtos, T. A. (2011). Fuzzy cognitive map based approach for predicting crop production as a basis for decision support system in precision agriculture application. Applied Soft Computing, 11(4), 3643-3657.

Pilarski, T., Happold, M., Pangels, H., Ollis, M., Fitzpatrick, K. and Stentz, A. (2002). The Demeter System for Automated Harvesting, Springer.

Snehal, S. S. and Sandeep, S. V. (2014). Agricultural crop yield prediction using artificial neural network approach. International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, 2(1), 683-686.

Tajik, S., Ayoubi, S. and Nourbakhsh, F. (2012). Prediction of soil enzymes activity by digital terrain analysis: Comparing artificial neural network and multiple linear regression models. Environmental Engineering Science, 29(8), 798-806.

Wolfert, S., L. Ge, C. Verdouw and M. J. Bogaardt (2017). Big data in smart farming- a review. Agricultural Systems, 153, 69-80.