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ADVANCES IN AGRICULTURE SCIENCES VOLUME III

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Advances in Agriculture Sciences Volume III

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PREFACE

Agriculture, being the cornerstone of human civilization, has undergone remarkable transformations over centuries. However, in today's rapidly changing world, the challenges facing agriculture are more complex and multifaceted than ever before. From feeding a growing global population to mitigating the impact of climate change, the demands placed upon the agricultural sector are immense.

In response to these challenges, scientists, researchers, and practitioners from around the globe have been tirelessly working to push the boundaries of agricultural knowledge and practice. Their relentless pursuit of innovation has led to remarkable discoveries and novel solutions that hold the potential to revolutionize the way we produce food, manage resources, and safeguard the environment.

"Advances in Agriculture Sciences" serves as a testament to the dedication and ingenuity of these individuals. Through a collection of insightful chapters, this book offers a comprehensive overview of cutting-edge research and emerging trends across various domains of agricultural science. From precision farming and biotechnology to sustainable practices and digital agriculture, each chapter delves into the latest developments and their implications for the future of farming.

Moreover, this book aims to foster interdisciplinary collaboration and knowledge exchange among researchers, practitioners, policymakers, and stakeholders in the agricultural community. By bringing together diverse perspectives and expertise, we hope to inspire dialogue, spark innovation, and drive positive change across the agricultural landscape.

As we navigate the complexities of the 21st century, the importance of agricultural science in addressing global challenges cannot be overstated. It is our sincere hope that "Advances in Agriculture Sciences" will serve as a valuable resource for anyone seeking to deepen their understanding of the dynamic field of agriculture and contribute to its continued advancement.

We extend our heartfelt gratitude to all the authors who have contributed their expertise and insights to this book. Their contributions have been instrumental in shaping this endeavor and enriching the discourse on agricultural innovation.

Editors

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ASSESSING THE EFFECTS OF MULTIPLE STRESSORS IN ECOTOXICOLOGY: CHALLENGES AND APPROACHES

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Abstract:

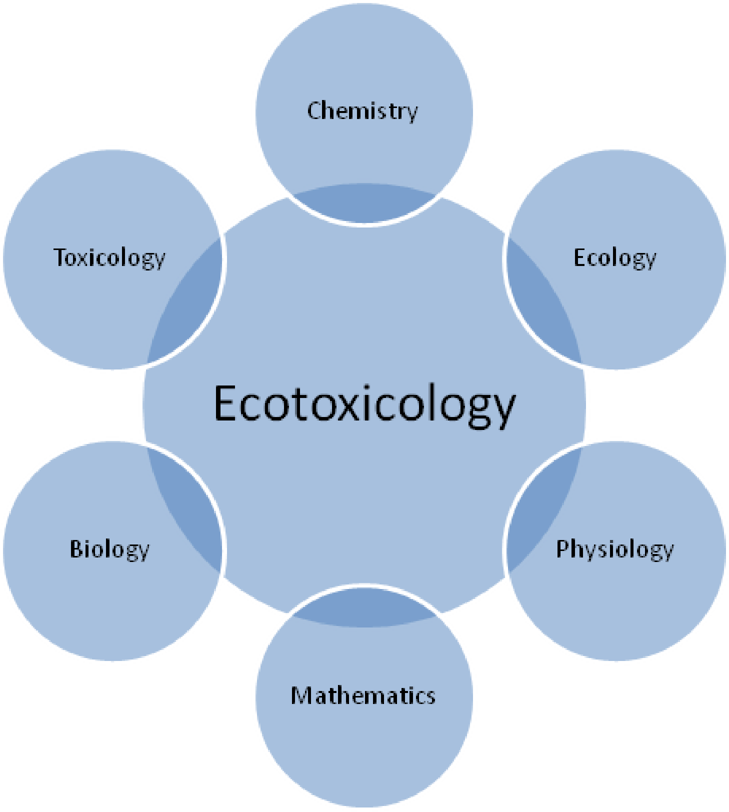
Ecotoxicology is an interdisciplinary field of environmental science that investigates the harmful effects of chemicals and contaminants on ecosystems. It focuses on assessing the risks and impacts of pollutants and developing strategies to mitigate their effects. Ecotoxicologists study the toxic effects of pollutants on various organisms, ranging from plants to microorganisms, and examine both direct and indirect effects on ecosystems. Determining dose-response relationships and understanding complex interactions between pollutants, species, and environmental factors are key challenges in ecotoxicology. Ecotoxicologists utilize laboratory studies, field studies, mathematical models, and monitoring programs to assess and predict the effects of pollutants. Research in ecotoxicology also includes the study of emerging pollutants, such as pharmaceuticals, personal care products, and nanomaterials, as well as the effects of multiple stressors on organisms and ecosystems.

Keywords: Ecotoxicology, Effect of Ecotoxicity, Techanical approaches

Introduction:

Environmental toxicology emerged as a science in response to growing concerns about the effects of chemicals and pollutants on the environment and human health. The roots of environmental toxicology can be traced to the mid-20th century when scientists began to investigate the harmful effects of chemical substances on ecosystems. Rachel Carson's groundbreaking book "Silent Spring," published in 1962, raised public awareness of the environmental effects of pesticides, especially DDT, on wildlife and ecosystems [1].

Scientists realized that pollutants could have detrimental effects not only on individual organisms but also on entire ecosystems. They began studying the impacts of chemicals on population dynamics, biodiversity, and ecological processes. These studies highlighted the interconnectedness of organisms and their environment. Scientists developed standardized methods for assessing the toxicity of chemicals. These included acute and chronic toxicity tests using various organisms, such as fish, invertebrates, and plants. Researchers also began studying the mechanisms of toxicity at the cellular and molecular levels. The development of advanced analytical techniques, such as high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), and molecular biology tools, greatly enhanced the ability to detect and quantify pollutants in environmental samples. These techniques facilitated more accurate assessments of exposure and toxicity [2-4].

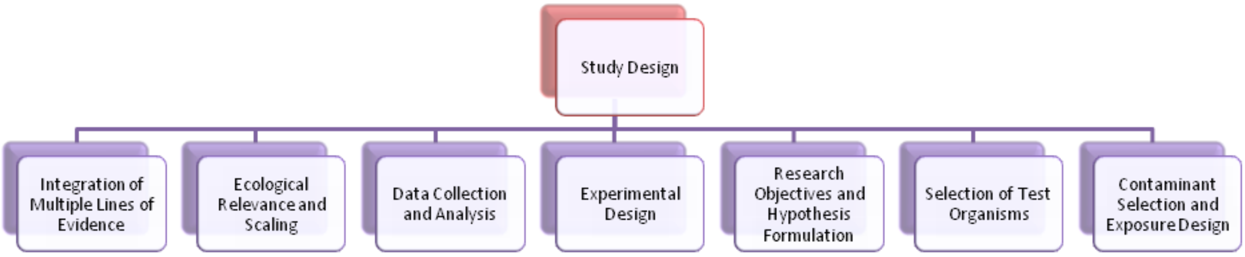


The recognition of environmental issues and the need for international cooperation led to increased global awareness of environmental toxicology. Organizations such as the United Nations Environment Programme (UNEP) and the World Health Organization (WHO) have played important roles in promoting research, sharing knowledge, and establishing guidelines for environmental protection. Environmental toxicology research has had significant applied implications. It has influenced policy decisions, the development of regulations, and the adoption of more sustainable practices. It has also contributed to the field of environmental risk assessment, helping to evaluate and manage the potential risks posed by chemicals and pollutants. Today, environmental toxicology continues to evolve, driven by new challenges such as emerging contaminants, climate change, and the need for sustainable solutions. It plays a crucial role in understanding the impacts of human activities on the environment, promoting environmental health, and informing decision-making processes to protect ecosystems and human well-being.

Scientific approach of ecotoxicology

The scientific approach of ecotoxicology involves systematic investigation and research to understand the effects of pollutants on ecosystems and living organisms. It employs a variety of scientific methods and techniques to gather data, analyze the impacts of pollutants, and draw conclusions based on empirical evidence [5-7]. Here are the key components of the scientific approach in ecotoxicology:

Study design: Ecotoxicological studies begin with careful planning and design to ensure valid and reliable results. Researchers define clear objectives, select appropriate study organisms and ecosystems, determine exposure scenarios, and establish suitable controls [8]. Factors such as duration, concentration, and frequency of exposure are considered in study design.



Exposure assessment: Ecotoxicologists assess how organisms are exposed to pollutants in their environment. They measure concentrations of pollutants in air, water, soil, sediment, or biota samples. Various sampling methods, such as grab sampling, passive sampling, or biomonitoring, are employed to collect representative data on pollutant levels and exposure patterns. Exposure assessment plays a vital role in ecotoxicology by providing a comprehensive understanding of how living organisms come into contact with environmental contaminants. It involves the measurement and evaluation of exposure pathways, routes, and concentrations to determine the potential risks posed by pollutants. Exposure assessment is a critical component of ecotoxicology, providing valuable information on how contaminants enter and interact with living organisms and ecosystems. By identifying exposure pathways, measuring contaminant levels, considering bioavailability and bioaccumulation, and utilizing modeling approaches, researchers can assess the potential risks of environmental contaminants. This knowledge is essential for effective risk management, pollution prevention, and the preservation of ecological integrity. By employing a systematic and multidisciplinary approach to exposure assessment, ecotoxicologists contribute to our understanding of the impacts of contaminants and help ensure the protection and sustainability of our environment [9-10].

Toxicity testing: Toxicity tests are conducted to assess the effects of pollutants on organisms. These tests involve exposing organisms to various concentrations of pollutants under controlled laboratory conditions. Common test organisms include fish, invertebrates, algae, and bacteria. The tests measure parameters such as mortality, growth, reproduction, behavior, enzyme activity, and genetic responses to determine the toxic effects. Toxicity testing is a fundamental aspect of ecotoxicology that focuses on evaluating the harmful effects of environmental contaminants on living organisms. These tests provide crucial data for understanding the potential risks and impacts of pollutants on both individual organisms and ecological systems. Toxicity testing is a crucial aspect of ecotoxicology, allowing researchers to assess the potential harmful effects of environmental contaminants on living organisms. Through the careful selection of test organisms, the establishment of dose-response relationships, and the measurement of various endpoints, toxicity testing provides valuable insights into the risks posed by contaminants. Standardization, validation, and the development of alternative methods further enhance the accuracy, reliability, and ethical considerations of toxicity testing in ecotoxicology. By employing these principles and methodologies, ecotoxicologists contribute to our understanding of the impacts of contaminants on ecosystems and aid in the development of effective environmental management strategies [11].

Field studies: Field studies provide real-world insights into the effects of pollutants on ecosystems and living organisms. Researchers conduct surveys and long-term monitoring to assess pollutant levels, observe population dynamics, measure species abundance, and evaluate ecosystem health. Field studies provide valuable data on the impacts of pollutants in natural settings. Field studies play a critical role in ecotoxicology by examining the effects of environmental contaminants in real-world settings. These studies involve direct observations and measurements in natural habitats, allowing researchers to assess the ecological impacts of contaminants on organisms and ecosystems. Field studies provide valuable insights into the behavior, distribution, bioaccumulation, and long-term effects of contaminants, complementing laboratory-based research. Field studies are crucial in ecotoxicology as they bridge the gap between laboratory-based research and real-world environmental conditions. By examining contaminants in natural habitats, field studies provide insights into long-term exposure, multi-species interactions, bioaccumulation, and the responses of ecosystems to contaminants. The integration of multiple lines of evidence and the relevance of findings to environmental management make field studies invaluable for understanding and addressing the ecological impacts of contaminants. Continued field-based research is essential for preserving environmental integrity and safeguarding the health of ecosystems and human populations.

Data analysis: Ecotoxicologists employ statistical methods and data analysis techniques to interpret the results of their studies. They analyze the dose-response relationships, assess the significance of observed effects, and quantify the risks posed by pollutants. Statistical modeling is often used to extrapolate laboratory findings to natural ecosystems and predict potential impacts. Data analysis is a fundamental component of ecotoxicology, enabling researchers to extract meaningful insights from collected data and unravel the impacts of contaminants on living systems. Ecotoxicological data can be complex and multidimensional, requiring appropriate statistical and analytical techniques to identify patterns, assess relationships, and draw conclusions.

Ecological risk assessment: Ecotoxicology contributes to ecological risk assessment by integrating data on exposure, toxicity, and ecological effects. Risk assessment involves evaluating the likelihood and magnitude of adverse effects on ecosystems, identifying sensitive species or habitats, and estimating the potential ecological consequences of pollutant exposure. It helps in setting environmental standards and making informed decisions for pollution management. Ecological risk assessment is a critical tool in ecotoxicology for evaluating the potential harm of contaminants to ecosystems [12-15]. By combining hazard identification, exposure assessment, effects assessment, risk characterization, and informed decision-making, it provides a comprehensive understanding of the risks associated with contaminants. Ecological risk assessment informs the development of risk management strategies and helps protect ecosystems, species, and human health from the adverse effects of contaminants. Continued research and collaboration between scientists, policymakers, and stakeholders are crucial for improving ecological risk assessment practices and promoting sustainable environmental management.

Peer review and scientific communication: Ecotoxicological studies undergo rigorous peer review by experts in the field before publication. Peer review ensures the quality and validity of the research. Scientific communication is essential for sharing findings, knowledge, and methodologies within the scientific community. Conferences, journals, and scientific publications facilitate the dissemination of ecotoxicological research. Scientific communication is crucial in ecotoxicology to bridge the gap between research and real-world impact. By employing clear and accessible language, targeted communication strategies, visualization techniques, storytelling, engaging the media, promoting open access, and fostering collaboration and public engagement, researchers can effectively communicate their findings and raise awareness about the ecological impacts of contaminants. Effective scientific communication enhances the understanding of environmental issues, informs decision-making processes, and facilitates the implementation of sustainable practices for the protection of ecosystems and human well-being. The scientific approach of ecotoxicology emphasizes objectivity, reproducibility, and evidence-based decision-making. It involves interdisciplinary collaboration, adherence to ethical standards, and continuous improvement in study methodologies. Through the scientific approach, ecotoxicology provides essential insights into the impacts of pollutants, aids in environmental protection, and contributes to the development of sustainable practices for the well-being of ecosystems and human populations.

Toxicant absorption routes and kinetics

Toxicants can enter organisms through various routes, and their uptake and distribution within the body can follow different kinetics. Routes and kinetics of toxicant uptake refer to the pathways by which contaminants enter an organism's body and the processes that govern their absorption, distribution, metabolism, and elimination within the organism. Understanding these routes and kinetics is essential in ecotoxicology as it determines the exposure and potential toxicity of contaminants to organisms and helps assess their overall ecological impact[16-18]. Here are the common routes of toxicant uptake and the kinetics associated with each:

Inhalation: Inhalation is a route of toxicant uptake where substances are absorbed through the respiratory system. Gases, vapors, and airborne particles can be inhaled into the lungs. The kinetics of uptake depends on factors such as the solubility of the toxicant, the size of the particles, and the duration and intensity of exposure. Once in the lungs, the toxicant can be rapidly absorbed into the bloodstream and distributed to target organs.

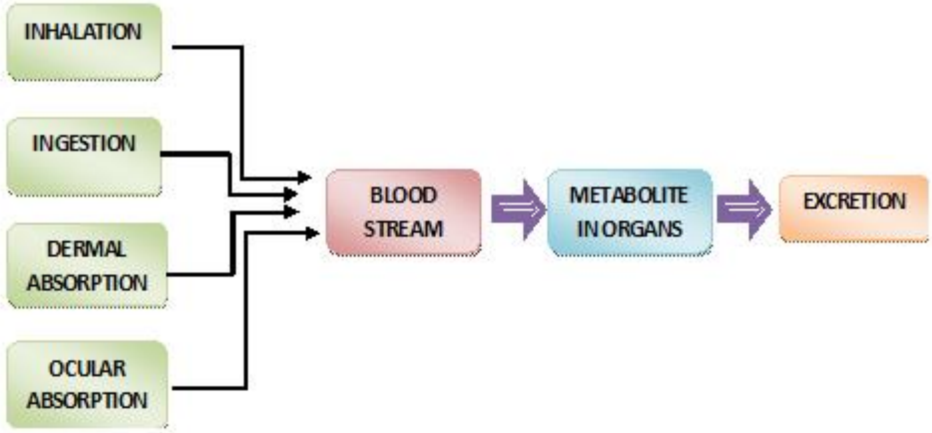
Ingestion: Ingestion involves the intake of toxicants through the mouth via food, water, or other materials. The kinetics of uptake in the gastrointestinal tract depend on factors such as the solubility and chemical properties of the toxicant, the presence of food or other substances that may affect absorption, and the rate of transit through the digestive system. Absorption can occur in the stomach, intestines, or directly through the walls of the gastrointestinal tract into the bloodstream.

Dermal absorption: Dermal absorption occurs when toxicants come into contact with the skin and are absorbed through the skin layers. The kinetics of dermal absorption depend on factors such as the chemical properties of the toxicant, the condition of the skin (e.g., intact or damaged), the area of exposure, and the duration and intensity of contact. Some toxicants can penetrate the skin and enter the bloodstream directly, while others may undergo metabolism or accumulation in the skin layers.

Injection: Injection is an artificial route of toxicant uptake, often used in laboratory studies or medical procedures. Substances can be injected directly into the bloodstream or other body compartments through methods such as intravenous, intramuscular, or subcutaneous injections. The kinetics of uptake in these cases can be rapid, as the toxicant bypasses barriers and is introduced directly into circulation.

The kinetics of toxicant distribution within the body depend on various factors, including the physicochemical properties of the toxicant, its solubility in different body fluids, and the physiological characteristics of the organism. Once absorbed, toxicants can be distributed throughout the body via the bloodstream [19-21]. They can accumulate in specific organs or tissues based on factors such as their affinity for certain tissues, metabolic processes, and binding to cellular receptors or proteins.

It's important to note that the kinetics of toxicant uptake and distribution can vary significantly depending on the specific toxicant, the route of exposure, and the characteristics of the organism being exposed. These factors play a crucial role in determining the toxicant's potential for adverse effects and the development of appropriate strategies for exposure prevention or mitigation.



Routes and kinetics of toxicant uptake

Methodological approaches in environmental toxicology

When studying environmental toxicology, various methodological approaches are employed to assess the impacts of pollutants on organisms and ecosystems. These approaches can include laboratory experiments, field studies, modeling, and data analysis. Methodological approaches in environmental toxicology encompass a range of techniques and tools used to study the effects of contaminants on organisms and ecosystems. These approaches provide valuable insights into the mechanisms of toxicity, the assessment of exposure and risks, and the development of mitigation strategies [22-25]. Here are some commonly used methodological approaches in environmental toxicology:

Laboratory experiments: Laboratory toxicity testing is a key methodological approach in environmental toxicology used to assess the effects of contaminants on organisms under controlled conditions. This approach involves conducting experiments in a laboratory setting using standardized protocols to determine the toxicity of substances and their potential impacts on various test organisms. Laboratory experiments provide controlled conditions for studying the effects of pollutants on organisms. These experiments typically involve exposing organisms to varying concentrations of a toxicant under controlled settings. Various endpoints, such as mortality, growth, reproduction, behavior, and biochemical responses, can be measured to assess the toxic effects. Laboratory experiments help establish cause-and-effect relationships, determine dose-response relationships, and investigate underlying mechanisms of toxicity. Laboratory toxicity testing provides valuable information on the potential effects and risks of contaminants to organisms. It helps in understanding dose-response relationships, establishing toxicity thresholds, comparing the toxicities of different substances, and providing data for regulatory decision-making and risk assessment in environmental management. However, it is important to recognize that laboratory toxicity tests represent controlled conditions and may not fully replicate the complexities of real-world ecosystems. Thus, results from laboratory tests should be interpreted with caution and complemented with other lines of evidence, such as field studies and modeling, for a comprehensive understanding of environmental risks.

Field studies: Field studies involve conducting research in natural environments to assess the effects of pollutants on ecosystems and organisms. Researchers collect samples from the environment, such as water, soil, sediments, or biota, and analyze them for pollutant concentrations. Field studies may also involve monitoring populations, assessing community structure, and observing ecological interactions. Field data provides valuable insights into real-world exposure scenarios, long-term effects, and the ecological relevance of laboratory findings.

Ecological surveys: Ecological surveys are conducted to assess the distribution, abundance, and health of organisms in ecosystems exposed to pollutants. These surveys often involve sampling and monitoring various species, including plants, animals, and microorganisms. Surveys can include biodiversity assessments, population surveys, and habitat characterization. By comparing exposed and unexposed areas, researchers can identify potential impacts of pollutants on ecosystems and assess the recovery of ecosystems after pollutant removal.

Biomarkers and bioindicators: Biomarkers are measurable indicators of exposure or effects at the molecular, cellular, or physiological level. They can include changes in gene expression, enzyme activity, DNA damage, or physiological responses. Bioindicators, on the other hand, are organisms or species that are particularly sensitive to pollutants or are easily sampled and monitored. The use of biomarkers and bioindicators allows for the early detection of pollutant impacts and the assessment of ecological health.

Modeling and risk assessment: Mathematical models are used to simulate and predict the fate, transport, and effects of pollutants in the environment. Models can help estimate exposure levels, predict the bioaccumulation of pollutants in food chains, and assess the potential risks to organisms and ecosystems. Risk assessment combines data from toxicity studies, exposure assessments, and ecological information to evaluate the potential risks posed by pollutants and informs decision-making processes.

Data analysis and statistical methods: Data analysis plays a crucial role in environmental toxicology. Statistical methods are employed to analyze and interpret data, establish dose-response relationships, assess the significance of effects, and identify patterns or trends. Advanced statistical techniques, such as multivariate analysis or time-series analysis, can be used to analyze complex data sets and identify key factors influencing pollutant impacts.

Meta-analysis: Meta-analysis involves the synthesis and analysis of data from multiple studies to draw overarching conclusions and identify general trends. It allows for the integration of findings from different studies and enhances the statistical power of the analysis. Meta-analysis is particularly useful for identifying consistent patterns across studies and understanding the overall impacts of pollutants.

These methodological approaches in environmental toxicology provide a comprehensive understanding of the impacts of pollutants on ecosystems and organisms. By combining different approaches, researchers can generate robust and reliable data to inform environmental management, policy development, and pollution control strategies [26].

Effect of environmental toxicology

Ecotoxicity refers to the harmful effects of substances on ecosystems and the organisms within them. Several factors can influence the ecotoxicity of substances. Understanding these factors is essential for assessing the potential risks to ecosystems and implementing effective environmental management strategies [27-29]. Here are some key factors that can affect ecotoxicity:

Species sensitivity: Different species exhibit varying sensitivities to toxic substances. Some species may be more susceptible to certain pollutants due to physiological, biochemical, or behavioral characteristics. Factors such as life stage, reproductive status, and habitat specialization can influence species sensitivity to toxicants. Understanding the range of species affected and their sensitivity levels is crucial for assessing the potential ecological impacts of pollutants.

Trophic level: The position of an organism within the food chain, or trophic level, can affect its exposure and susceptibility to toxic substances. Organisms at higher trophic levels, such as predators, may accumulate higher concentrations of pollutants through the process of biomagnification. Consequently, they can experience more pronounced toxic effects compared to organisms at lower trophic levels. The trophic structure of an ecosystem influences the potential for toxicant transfer and magnification through the food web.

Bioaccumulation and biomagnification: Substances that have the potential to bioaccumulate and biomagnify in the food chain can pose significant ecotoxicological risks. Bioaccumulation refers to the accumulation of substances within the tissues of organisms over time, while biomagnification describes the increase in pollutant concentrations at higher trophic levels. Substances with high bioaccumulation and biomagnification potential can reach toxic levels in top predators, leading to adverse effects on their health and population dynamics.

Environmental conditions: The physical and chemical conditions of the environment can influence the ecotoxicity of substances. Factors such as temperature, pH, salinity, oxygen levels, and nutrient availability can affect the uptake, distribution, and toxicity of pollutants. Environmental conditions can also interact with toxicants to influence their transformation, persistence, and bioavailability. Changes in environmental conditions, such as climate change or pollution-induced alterations, can modify the sensitivity of ecosystems to toxic substances.

Interactions with other substances: Substances in the environment can interact with one another, either enhancing or reducing their toxic effects. Synergistic interactions occur when the combined effect of multiple substances is greater than the sum of their individual effects. Antagonistic interactions, on the other hand, lead to reduced toxicity when two or more substances counteract each other's effects. These interactions can occur between pollutants or between pollutants and naturally occurring compounds present in the environment.

Exposure pathways: The route and duration of exposure to toxic substances can influence their ecotoxicity. Different exposure pathways, such as direct contact, inhalation, or ingestion, can affect the absorption, distribution, and metabolism of pollutants in organisms. The duration and frequency of exposure can determine the cumulative effects of toxicants and the potential for chronic toxicity.

Habitat characteristics: The characteristics of the habitat, including water quality, sediment composition, and vegetation, and ecological interactions, can influence the ecotoxicity of substances. Habitat structure and complexity can affect the exposure and vulnerability of organisms to pollutants. The presence of sensitive habitats or protected species in an area can increase the concern for ecotoxicological impacts.

Understanding these factors and their interactions is crucial for assessing the potential ecotoxicological risks of substances and developing appropriate management strategies. By considering the complex interplay of these factors, scientists and policymakers can make informed decisions to protect ecosystems and mitigate the adverse effects of pollutants on biodiversity and ecosystem functioning.

Effect of metals and other chemicals

Metals and other chemicals play a significant role in ecotoxicity due to their potential to cause adverse effects on ecosystems and organisms. Here are some specific considerations regarding metals and other chemicals in ecotoxicology:

Metals:

Heavy metals: Heavy metals such as lead, mercury, cadmium, arsenic, and chromium are of particular concern in ecotoxicology. They are naturally occurring elements but can become toxic at elevated concentrations. Heavy metals can accumulate in organisms, leading to chronic toxicity and biomagnification in food chains.

Bioavailability: The bioavailability of metals is a crucial factor in their ecotoxicity. The form and speciation of metals determine their toxicity and ability to be taken up by organisms. Factors such as pH, redox potential, organic matter content, and complexation with ligands influence metal bioavailability.

Metal interactions: Metals can interact with other metals or chemicals in the environment, leading to synergistic or antagonistic effects. These interactions can alter the toxicokinetics and toxicodynamics of metals, enhancing or reducing their overall toxicity.

Threshold effects: Some metals exhibit threshold effects, where adverse effects occur only above a certain concentration or dose. Below this threshold, the metal may not cause significant harm. Threshold effects are important to consider when establishing regulatory guidelines and environmental standards.

Other chemicals:

Organic pollutants: Organic pollutants, such as pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, and pharmaceuticals, can have diverse toxic effects on ecosystems. They can persist in the environment, bioaccumulate in organisms, and cause both acute and chronic toxicity.

Endocrine Disrupting Chemicals (EDCs): EDCs are chemicals that interfere with the hormonal systems of organisms, affecting reproductive, developmental, and physiological processes. EDCs include substances like certain pesticides, plasticizers (e.g., bisphenol A), and flame retardants (e.g., polybrominated diphenyl ethers).

Emerging contaminants: The ecotoxicity of emerging contaminants, such as microplastics, nanomaterials, and pharmaceutical residues, is an area of growing concern. These substances can have diverse and potentially harmful effects on ecosystems, including impacts on organisms' feeding, reproduction, and behavior.

Persistence and biodegradability: The persistence and biodegradability of chemicals influence their potential for long-term environmental impact. Chemicals that persist in the environment can bioaccumulate and have prolonged effects on ecosystems, while those that readily biodegrade may have shorter-lived impacts.

Mixtures and cocktail effects: Organisms are often exposed to complex mixtures of chemicals in the environment. The combined effects of multiple chemicals, known as cocktail effects, can differ from the effects of individual chemicals alone. Synergistic or antagonistic interactions between chemicals within mixtures can significantly influence ecotoxicological outcomes.

Understanding the behavior, fate, and toxicity of metals and other chemicals is essential for assessing their potential ecological risks. Through ecotoxicological studies, scientists aim to determine safe exposure levels, understand mechanisms of toxicity, and develop effective management strategies to mitigate the adverse impacts of metals and other chemicals on ecosystems and organisms.

Risk assessment and risk management

Ecological risk assessment and risk management are specific branches of risk assessment and management that focus on assessing and managing the potential risks posed by pollutants to ecosystems and their components[30]. Here's an overview of ecological risk assessment and risk management:

Ecological risk assessment: Ecological risk assessment involves the evaluation of potential adverse effects of pollutants on ecosystems, including plants, animals, and their habitats. The primary goal is to understand and quantify the potential ecological impacts resulting from exposure to contaminants. The assessment takes into account both direct and indirect effects of pollutants on ecological receptors, such as changes in population dynamics, species composition, habitat quality, and ecosystem functions.

Key steps in ecological risk assessment include:

Problem formulation: Defining the scope and objectives of the assessment, identifying the ecological receptors and stressors of concern, and developing an assessment framework.

Exposure assessment: Evaluating the exposure pathways and levels of contaminants in the environment, including air, water, sediment, and biota. This involves assessing how organisms come into contact with and absorb pollutants.

Effects assessment: Investigating the potential adverse effects of contaminants on ecological receptors, including acute and chronic toxicity, reproductive impairment, changes in behavior, and impacts on population dynamics and ecosystem processes.

Risk characterization: Integrating exposure and effects data to estimate the likelihood and magnitude of adverse ecological effects. Uncertainties and variability are considered, and the level of risk is characterized based on scientific evidence.

Ecological risk management: Ecological risk management involves the development and implementation of strategies and actions to reduce or mitigate the identified risks to ecosystems. The aim is to protect and conserve ecological resources and maintain ecosystem integrity. Risk management decisions consider the findings from the risk assessment and balance environmental, social, and economic factors.

Key aspects of ecological risk management include:

Risk reduction strategies: Developing and implementing measures to minimize the release and exposure of contaminants in the environment. This may involve pollution prevention, control technologies, regulatory measures, and best management practices.

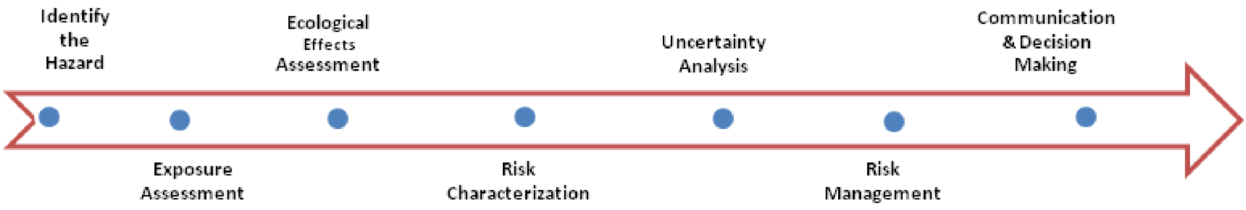
Habitat restoration and conservation: Implementing initiatives to restore and conserve habitats and ecosystems that have been impacted by pollutants. This includes actions such as habitat restoration, species conservation, and the establishment of protected areas.

Monitoring and adaptive management: Regular monitoring of ecological indicators and the effectiveness of risk management measures. This allows for adjustments and improvements in management strategies based on new information and feedback from monitoring efforts.

Stakeholder engagement: Engaging relevant stakeholders, including scientists, regulators, policymakers, local communities, and industry, in the decision-making process. This ensures transparency, understanding of concerns, and integration of diverse perspectives.

Compliance and enforcement: Implementing regulations, standards, and enforcement mechanisms to ensure compliance with environmental laws and guidelines. This includes monitoring compliance, conducting inspections, and taking enforcement actions when necessary.

Ecological risk assessment and risk management provide a framework for understanding, evaluating, and addressing the potential risks that pollutants pose to ecosystems [31,32]. By identifying and managing these risks, decision-makers can work towards protecting and conserving the environment and its valuable ecological resources.



Risk assessment for Ecotoxicology

Technical approaches of ecotoxicology

Ecotoxicology employs various technical approaches to study the effects of pollutants on ecosystems and organisms. These approaches involve a range of laboratory and field-based techniques, as well as analytical methods for assessing toxicity and ecological impacts [33-35]. Here are some common technical approaches used in ecotoxicology:

Laboratory toxicity tests: Laboratory toxicity tests involve exposing organisms to controlled concentrations of pollutants under controlled conditions. These tests can assess acute and chronic toxicity, determine dose-response relationships, and evaluate sub-lethal effects. Standardized test organisms, such as Daphnia, fish, and algae, are commonly used in these tests. Laboratory tests provide important data for understanding the effects of pollutants on organisms and for establishing toxicity thresholds.

Field studies: Field studies involve conducting research directly in natural ecosystems to assess the effects of pollutants on resident organisms. Field sampling techniques are used to collect organisms from contaminated sites, and their health and population dynamics are assessed. Field studies provide valuable insights into real-world scenarios, considering the complexity of ecological interactions and the potential for multiple stressors.

Mesocosm and microcosm experiments: Mesocosm and microcosm experiments involve creating enclosed, controlled ecosystems in the laboratory or field. These experiments allow for the manipulation of pollutant concentrations and the study of ecological processes and community-level responses. Mesocosms and microcosms provide a middle ground between laboratory tests and field studies, allowing researchers to investigate ecological interactions while maintaining experimental control.

Biomarker analysis: Biomarker analysis involves measuring specific biochemical, physiological, or genetic responses in organisms that indicate exposure to pollutants or associated toxic effects. Biomarkers can include enzymatic activities, gene expression profiles, oxidative stress markers, or specific physiological responses. Biomarker analysis provides valuable information on the early biological effects of pollutants and can help assess sub-lethal impacts on organisms.

Bioaccumulation studies: Bioaccumulation studies focus on determining the uptake, distribution, and accumulation of pollutants in organisms. These studies often involve the analysis of pollutant concentrations in various tissues or compartments of organisms over time. Bioaccumulation studies provide insights into the potential for pollutants to accumulate in food chains and biomagnify in higher trophic levels.

Ecological modeling: Ecological modeling uses mathematical and computational models to simulate the fate and transport of pollutants in ecosystems and predict their potential effects. These models consider various factors, such as pollutant concentrations, exposure pathways, ecological interactions, and population dynamics. Ecological modeling helps in understanding the long-term impacts of pollutants and aids in risk assessment and management.

Chemical analysis: Chemical analysis techniques are used to measure pollutant concentrations in environmental samples, such as water, sediment, soil, and biota. Analytical methods, including gas chromatography, liquid chromatography, mass spectrometry, and atomic absorption spectroscopy, are used to identify and quantify specific pollutants. Chemical analysis provides essential data for exposure assessment, determining pollutant sources, and understanding the bioavailability of contaminants.

These technical approaches in ecotoxicology enable scientists to assess the potential risks of pollutants, understand their mechanisms of toxicity, and evaluate their ecological impacts. By employing a combination of laboratory, field, and analytical techniques, ecotoxicologists can provide valuable insights into the effects of pollutants on ecosystems and contribute to informed decision-making for environmental protection and management.

Regulation of toxic substances

The regulation of toxic substances involves the implementation of legal approaches to ensure the protection of human health and the environment from the adverse effects of such substances. Here are some possible legal approaches that can be used to regulate toxic substances:

Regulatory frameworks: Governments can establish comprehensive regulatory frameworks that outline the requirements and standards for the production, use, and disposal of toxic substances. These frameworks often include laws, regulations, and guidelines that govern the entire life cycle of toxic substances, from their manufacture to their ultimate fate in the environment.

Chemical registration and evaluation: Governments can require the registration and evaluation of toxic substances before they are introduced into the market. This process involves manufacturers or importers providing detailed information about the chemical properties, hazards, and potential risks of the substance. Regulatory authorities can then assess the data and determine whether the substance can be safely used or if additional restrictions are necessary.

Hazard assessment and classification: Governments can establish systems for the hazard assessment and classification of toxic substances. These systems categorize substances based on their potential to cause harm to human health or the environment. Hazard assessments consider factors such as acute toxicity, chronic toxicity, carcinogenicity, mutagenicity, and ecotoxicity. Classification systems help in identifying and prioritizing substances of concern for regulatory actions.

Risk assessment and management: Risk assessment and management approaches involve evaluating the potential risks associated with the use or exposure to toxic substances and developing strategies to mitigate those risks. Risk assessments consider factors such as exposure pathways, toxicity data, exposure levels, and vulnerable populations. Risk management strategies may include setting exposure limits, implementing control measures, establishing safe handling procedures, or phasing out the use of certain toxic substances.

Labeling and packaging requirements: Governments can enforce labeling and packaging requirements for toxic substances. This includes mandating the use of specific labels that provide information on the hazards, proper handling, and disposal of the substances. Clear labeling helps users and consumers make informed decisions and take necessary precautions to minimize exposure to toxic substances.

Bans and restrictions: Governments have the authority to ban or restrict the production, import, sale, or use of certain toxic substances. This is typically done for substances that pose significant risks to human health or the environment and have no safe or acceptable use. Bans and restrictions can be implemented based on scientific evidence, emerging concerns, or international agreements.

International agreements and harmonization: International agreements and harmonization efforts play a crucial role in regulating toxic substances. Examples include the Stockholm Convention on Persistent Organic Pollutants (POPs), the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and the Basel Convention on the Control of Transboundary Movements of Hazardous

Wastes and Their Disposal. These agreements facilitate global cooperation and coordination in addressing the risks associated with toxic substances.

It's important to note that the specific legal approaches and regulations for toxic substances may vary across countries and regions. The regulatory frameworks are often developed based on scientific research, risk assessments, public input, and stakeholder consultations to ensure the protection of human health and the environment while considering social and economic factors.

Conclusion:

Ecotoxicology provides a comprehensive and interdisciplinary perspective on the effects of pollutants on ecosystems and the organisms within them. It focuses on understanding the mechanisms, evaluating the risks, and developing strategies to mitigate the impacts of toxic substances on the environment. Here's an overall perspective on ecotoxicology:

Interdisciplinary science: Ecotoxicology brings together concepts and methodologies from various scientific disciplines, including toxicology, ecology, chemistry, physiology, genetics, and environmental science. This interdisciplinary approach allows for a comprehensive understanding of the complex interactions between pollutants and ecosystems.

Protection of ecosystem health: Ecotoxicology emphasizes the importance of maintaining the health and integrity of ecosystems. It recognizes that pollutants can have cascading effects throughout the food chain and impact ecosystem processes, biodiversity, and overall ecosystem functioning. By studying these effects, ecotoxicologists aim to protect and preserve ecosystems for the benefit of both human and environmental well-being.

Multiple stressors: Ecotoxicology acknowledges that ecosystems are exposed to multiple stressors, including pollutants, habitat degradation, climate change, and invasive species. It seeks to understand how these stressors interact and synergistically affect organisms and ecosystems. By considering the cumulative impacts of multiple stressors, ecotoxicologists provide a more realistic assessment of ecological risks.

Chemicals of concern: Ecotoxicology focuses on a wide range of chemicals that can be harmful to ecosystems, including industrial chemicals, pesticides, heavy metals, pharmaceuticals, and emerging contaminants. It investigates the sources, fate, behavior, and effects of these chemicals in the environment. By identifying chemicals of concern, ecotoxicologists contribute to the development of regulations and strategies to minimize their impacts.

Risk assessment and management: Ecotoxicology plays a crucial role in assessing the risks posed by toxic substances and developing strategies for risk management and mitigation. Through hazard identification, exposure assessment, and risk characterization, ecotoxicologists provide scientific evidence for decision-making, policy development, and environmental management practices.

Conservation and restoration: Ecotoxicology contributes to the conservation and restoration of ecosystems impacted by pollutants. It provides insights into the recovery potential of ecosystems, the identification of critical habitats, and the development of strategies for habitat restoration. By understanding the effects of pollutants, ecotoxicologists inform conservation efforts and promote sustainable management practices.

Human health considerations: Ecotoxicology recognizes that the impacts of pollutants on ecosystems can ultimately affect human health through various pathways, including contaminated food and water sources. It aims to understand and quantify these risks, contributing to the development of regulations and measures to protect human populations from exposure to harmful substances.

Transdisciplinary collaboration: Ecotoxicology encourages collaboration and communication among scientists, policymakers, industries, and communities. It recognizes the importance of integrating scientific knowledge with societal values and concerns. By fostering transdisciplinary collaboration, ecotoxicologists strive to bridge the gap between science and decision-making, promoting evidence-based environmental management and sustainable development.

In summary, ecotoxicology provides a holistic perspective on the impacts of toxic substances on ecosystems, emphasizing the need for integrated approaches to assess, manage, and mitigate these impacts. It plays a vital role in protecting the environment, conserving biodiversity, and safeguarding human health in the face of increasing anthropogenic pressures and emerging environmental challenges.

References:

1. Institution, S. (n.d.). Silent Spring, Rachel Carson, 1962 | Smithsonian Institution. Smithsonian Institution. https://www.si.edu/object/silent-spring-rachel-carson-1962%3Anmah_1453548#:~:text=The%20book%20Silent%20Spring%20by,companies%20attacked%20it%20as%20unscientific.
2. Beyer, J., Jonsson, G., Porte, C., Krahn, M. M., & Ariese, F. (2010). Analytical methods for determining metabolites of polycyclic aromatic hydrocarbon (PAH) pollutants in fish bile: A review. Environmental Toxicology and Pharmacology, 30(3), 224–244. https://doi.org/10.1016/j.etap.2010.08.004
3. Vas, G., & Vékey, K. (2004). Solid-phase microextraction: a powerful sample preparation tool prior to mass spectrometric analysis. Journal of Mass Spectrometry, 39(3), 233–254. https://doi.org/10.1002/jms.606
4. Singh, J. P., & Mehta, A. (2020). Rapid and sensitive detection of mycotoxins by advanced and emerging analytical methods: A review. Food Science and Nutrition, 8(5), 2183–2204. https://doi.org/10.1002/fsn3.1474

5. Eggen, R. I., Behra, R., Burkhardt-Holm, P., Escher, B. I., & Schweigert, N. (2004). Peer Reviewed: Challenges in Ecotoxicology. Environmental Science & Technology, 38(3), 58A-64A. https://doi.org/10.1021/es040349c
6. Kahru, A., & Dubourguier, H. (2010). From ecotoxicology to nanoecotoxicology. Toxicology, 269(2–3), 105–119. https://doi.org/10.1016/j.tox.2009.08.016
7. Biochemical and Physiological Approaches in Ecotoxicology on JSTOR. (n.d.). https://www.jstor.org/stable/2389586
8. Moermond, C. T. A., Beasley, A., Breton, R. L., Junghans, M., Laskowski, R., Solomon, K. R., & Zahner, H. (2017). Assessing the reliability of ecotoxicological studies: An overview of current needs and approaches. Integrated Environmental Assessment and Management, 13(4), 640–651. https://doi.org/10.1002/ieam.1870
9. Hellou, J. (2010). Behavioural ecotoxicology, an "early warning" signal to assess environmental quality. Environmental Science and Pollution Research, 18(1), 1–11. https://doi.org/10.1007/s11356-010-0367-2
10. Handy, R. D., Owen, R. R., & Valsami-Jones, E. (2008). The ecotoxicology of nanoparticles and nanomaterials: current status, knowledge gaps, challenges, and future needs. Ecotoxicology, 17(5), 315–325. https://doi.org/10.1007/s10646-008-0206-0
11. Chapman, P. M., & Wang, F. (2001). Assessing sediment contamination in estuaries. Environmental Toxicology and Chemistry, 20(1), 3–22. https://doi.org/10.1002/etc.5620200102
12. Van Der Oost, R., Beyer, J., & Vermeulen, N. P. E. (2003). Fish bioaccumulation and biomarkers in environmental risk assessment: a review. Environmental Toxicology and Pharmacology, 13(2), 57–149. https://doi.org/10.1016/s1382-6689(02)00126-6
13. Van Aggelen, G., Ankley, G. T., Baldwin, W. M., Bearden, D. W., Benson, W. E., Chipman, J. K., Collette, T., Craft, J. A., Denslow, N. D., Embry, M. R., Falciani, F., George, S. L., Helbing, C. C., Hoekstra, P. F., Iguchi, T., Kagami, Y., Katsiadaki, I., Kille, P., Liu, L., . . . Yu, L. (2010). Integrating Omic Technologies into Aquatic Ecological Risk Assessment and Environmental Monitoring: Hurdles, Achievements, and Future Outlook. Environmental Health Perspectives, 118(1), 1–5. https://doi.org/10.1289/ehp.0900985
14. Ankley, G. T., Cureton, P. M., Hoke, R. A., Houde, M., Kumar, A., Kurias, J., Lanno, R. P., McCarthy, C., Newsted, J. L., Salice, C. J., Sample, B. E., Sepúlveda, M. S., Steevens, J. A., & Polesello, S. (2020). Assessing the Ecological Risks of Per- and Polyfluoroalkyl Substances: Current State-of-the Science and a Proposed Path Forward. Environmental Toxicology and Chemistry, 40(3), 564–605. https://doi.org/10.1002/etc.4869

15. Norton, S. J., Rodier, D. J., Van Der Schalie, W. H., Wood, W. A., Slimak, M. W., & Gentile, J. H. (1992). A framework for ecological risk assessment at the EPA. Environmental Toxicology and Chemistry, 11(12), 1663–1672. https://doi.org/10.1002/etc.5620111202
16. Baynes, R. E., & Hodgson, E. (2004). Absorption and Distribution of Toxicants. In John Wiley & Sons, Inc. eBooks (pp. 75–110). https://doi.org/10.1002/0471646776.ch6
17. O'Flaherty, E. J. (2003). Absorption, Distribution, and Elimination of Toxic Agents. In John Wiley & Sons, Inc. eBooks. https://doi.org/10.1002/0471231800.ch2
18. Yang, R., Brauner, C. J., Thurston, V., Neuman, J. G., & Randall, D. A. (2000). Relationship between toxicant transfer kinetic processes and fish oxygen consumption. Aquatic Toxicology, 48(2–3), 95–108. https://doi.org/10.1016/s0166-445x(99)00050-8
19. Tsaioun, K. (2016). Evidence-based absorption, distribution, metabolism, excretion (ADME) and its interplay with alternative toxicity methods. https://kops.uni-konstanz.de/handle/123456789/37782
20. Coecke, S., Pelkonen, O., Leite, S. B., Bernauer, U., Bessems, J., Bois, F. Y., Gundert-Remy, U., Loizou, G., Testai, E., & Zaldívar, J. (2013b). Toxicokinetics as a key to the integrated toxicity risk assessment based primarily on non-animal approaches. Toxicology in Vitro, 27(5), 1570–1577. https://doi.org/10.1016/j.tiv.2012.06.012
21. Yu, H., Nie, E., Xu, J., Yan, S., Cooper, W. E., & Song, W. (2013). Degradation of Diclofenac by Advanced Oxidation and Reduction Processes: Kinetic Studies, Degradation Pathways and Toxicity Assessments. Water Research, 47(5), 1909–1918. https://doi.org/10.1016/j.watres.2013.01.016
22. Portico. (n.d.). https://access.portico.org/Portico/auView?auId=ark:%2F27927%2Fphz14rgr0d3
23. Rodríguez-Moro, G., Ramírez-Acosta, S., Arias-Borrego, A., García-Barrera, T., & Gómez-Ariza, J. L. (2018). Environmental Metallomics. In Advances in Experimental Medicine and Biology (pp. 39–66). Springer Nature. https://doi.org/10.1007/978-3-319-90143-5_3
24. Belanger, S. E., Sanderson, H., Embry, M. R., Coady, K., DeZwart, D., Farr, B. A., Gutsell, S., Halder, M., Sternberg, R. M., & Wilson, P. W. (2015). It is time to develop ecological thresholds of toxicological concern to assist environmental hazard assessment. Environmental Toxicology and Chemistry, 34(12), 2864–2869. https://doi.org/10.1002/etc.3132
25. Renner, K. O., Foster, H. E., Routledge, E. J., & Scrimshaw, M. D. (2021). A Comparison of Different Approaches for Characterizing Microplastics in Selected Personal Care

Products. Environmental Toxicology and Chemistry, 41(4), 880–887. https://doi.org/10.1002/etc.5057
26. Alleva, E., Rankin, J., & Santucci, D. (1998). Methodological Analysis in Behavioral Toxicology: an Ethotoxicological Approach. Toxicology and Industrial Health, 14(1–2), 325–332. https://doi.org/10.1177/074823379801400120
27. Environmental Toxicology. (n.d.). Google Books. https://books.google.co.in/books?hl=en&lr=&id=zMCiWZiuTJsC&oi=fnd&pg=PP1&dq=Effect+of+Environmental+toxicology&ots=o2oNPgVnXv&sig=KHlLQOA-LlgMX8fq_jLQh9DXpxE#v=onepage&q=Effect%20of%20Environmental%20toxicology&f=false
28. Occupational, Industrial, and Environmental Toxicology. (n.d.). Google Books. https://books.google.co.in/books?hl=en&lr=&id=NnZ23IqU4SoC&oi=fnd&pg=PR7&dq=Effect+of+Environmental+toxicology&ots=DjgpATCFQd&sig=N25BxUm_TQJ5L07nsMo_VtWHl3g#v=onepage&q=Effect%20of%20Environmental%20toxicology&f=false
29. Carmen, B. (2022). Metabolomics in environmental toxicology: Applications and challenges. Trends in Environmental Analytical Chemistry, 34, e00161. https://doi.org/10.1016/j.teac.2022.e00161
30. Edwards, F. L., & Tchounwou, P. B. (2005). Environmental Toxicology and Health Effects Associated with Methyl Parathion Exposure – A Scientific Review. International Journal of Environmental Research and Public Health, 2(3), 430–441. https://doi.org/10.3390/ijerph2005030007
31. Mutti, A. (1999). Biological monitoring in occupational and environmental toxicology. Toxicology Letters, 108(2–3), 77–89. https://doi.org/10.1016/s0378-4274(99)00076-4
32. Matthews, R., Landis, W. G., & Matthews, G. (1996). The community conditioning hypothesis and its application to environmental toxicology. Environmental Toxicology and Chemistry, 15(4), 597–603. https://doi.org/10.1002/etc.5620150427
33. Bickham, J. W., Sandhu, S., Hebert, P. D. N., Chikhi, L., & Athwal, R. S. (2000). Effects of chemical contaminants on genetic diversity in natural populations: implications for biomonitoring and ecotoxicology. Mutation Research-reviews in Mutation Research, 463(1), 33–51. https://doi.org/10.1016/s1383-5742(00)00004-1
34. Behavioural Ecotoxicology. (n.d.). Google Books. https://books.google.co.in/books?hl=en&lr=&id=wDtfq_9P_4kC&oi=fnd&pg=PR11&dq=Technical+approaches+of+Ecotoxicology&ots=qEQFMlvWUM&sig=fIOh9dxmy

KvnoWPR6fPHo97GhZg#v=onepage&q=Technical%20approaches%20of%20Ecotoxicology&f=false

35. Vighi, M., & Villa, S. (2013). Ecotoxicology: The Challenges for the 21st Century. Toxics, 1(1), 18–35. https://doi.org/10.3390/toxics1010018
36. HeinOnline. (2021, March 8). About | HeinOnline. https://heinonline.org/HOL/LandingPage?handle=hein.journals/environ6&div=6&id=&page=
37. HeinOnline. (2021b, March 8). About | HeinOnline. https://heinonline.org/HOL/LandingPage?handle=hein.journals/yjor5&div=7&id=&page=
38. Au, W. W. (2002). Susceptibility of children to environmental toxic substances. International Journal of Hygiene and Environmental Health, 205(6), 501–503. https://doi.org/10.1078/1438-4639-00179

INCORPORATION OF DRUMSTICK LEAF POWDER AND DEFATTED SOYBEAN FLOUR IN INSTANT NOODLES

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Introduction:

Noodles are widely consumed throughout the world and it is a fast growing sector of the noodle industry (Owen, 2001). This is because instant noodles are convenient, easy to cook, low cost and have a relatively long shelf-life. Wheat flour which is usually used to make noodles is not only low in fibre and protein contents but also poor in essential amino acid, lysine. Flour of hard wheat (*Triticum aestivum* L.) is the main primary ingredient (Fu, 2008) and the addition of other ingredients like salt, starch, oil, guar gum etc. can help strengthen the structure and hence improve the firmness of the final product (Hou and Kruk 1998). Noodles have become internationally recognized food and worldwide consumption is on the rise. Noodle consumption has increased worldwide because of its convenience, nutritional quality, and palatability (Li *et al.*, 2012).

Drumstick (*Moringa oleifera)* is an important perennial vegetable crop and is now seen as one way of helping subsistence farmers make better use of their land and improve their living standards. A wide variety of nutritional and medicinal virtues have been attributed to its roots, bark, leaves, flowers, fruits and seeds (Kumar *et al.*, 2010). Phytochemical analyses have shown that its leaves are particularly rich in potassium, calcium, phosphorous, iron, vitamins A and D, essential amino acids as well as antioxidants such as β-carotene, vitamin C and flavonoids (Amaglo *et al.*, 2010; Gowrishankar *et al.*, 2010) because of this dehydrated drumstick leaves were taken for incorporating into noodles.

The soybean, a grain legume, is one of the richest and cheapest sources of plant protein that can be used to improve the diet of millions of people, especially the poor and low income earners in developing countries. The main ingredients of noodles are wheat, which is having deficiency of essential amino acid lysine, whereas soybean is richer in lysine and can be complement to wheat in noodles. Soybean protein is more economical than high priced meat protein and so they are considered as best source of protein especially in vegetarian diet. It increases nutritional status of vulnerable groups like pregnant woman, nursing mother, school going and young children (Khalid *et al.*, 2012). The objective of the present study was to investigate the nutritional quality of noodles incorporated with drumstick leaf powder and defatted soybean flour.

Materials and methods used to enhance the nutritional content of noodles

The leaves of KDM-01 (Bhagya) is a newly released drumstick variety of University of Horticultural Sciences, Bagalkot was used for the study. Defatted soybean flour was procured from Ahmed shopping centre, Bengaluru. Starch and guar gum was purchased from Aminghad Agencies, Dharwad and other ingredients like salt, starch, vegetable oil etc. were procured from local market Vidyagiri, Bagalkot.

Preparation of noodles

Noodles were prepared by mixing all the ingredients as per treatments shown in the Table 1. Among the seven treatments only control T_1 and treatment T_3 were taken for storage studies after the preliminary analysis.

Observations recorded

Moisture (%)

Moisture contents were measured by slightly modifying the hot air oven method (Anon, 1995). Empty stainless steel moisture dishes with lids were first dried into a pre-heated oven (100 ± 1°C) for 1 h. The dishes and lids were then cooled for 30 min in a desiccator. Approximately 5 g instant noodle pieces were accurately weighed into the pre-weighed dishes and placed into the oven with the lids placed under the respective dishes. These samples were dried at 105°C for 3 h and cooled in a desiccator for 30 min. The process of drying, cooling and weighing was repeated until constant weight obtained. Results were calculated in percentage using the following equation:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{\text{Weight of the sample}} \times 100$$

Where,

W_1 = Weight of the moisture cup and sample before heating

W_2 = Weight of the moisture cup and sample after heating

Protein (%)

Determination of protein content was carried out by micro kjedhal method which consists of wet digestion, distillation and titration. The protein content was determined by weighing 0.2g of dried noodle samples and transfer to a 250ml Kjeldahl flask care to see that no portion of the sample clings to the neck of the flask. To this 1 to 2 g of catalyst mixture (potassium sulphate 100g and copper sulphate 20g) and 10ml of concentrated H_2SO_4 was added. Flask was placed on the stand in the digestion chamber and continued the process of digestion until the colour of the digest is pale green. The digestion mixture was cooled by adding 30 ml of water. After digestion, distillation was carried out using 40% NaOH and 20% boric acid using methyl orange as an indicator and titrate against 0.1 N H_2SO_4. The protein content was calculated as follows:

$$\text{Nitrogen (\%)} = \frac{14.01 \text{ x ml titrate value of sample x N of } H_2SO_4 \text{ x } 100}{\text{Sample weight (g) x } 1000}$$

Protein content was obtained by converting nitrogen to protein by using conversion factor of 6.25

Protein (%) = 6.25 x Nitrogen (%)

Crude fibre (%)

Crude fibre estimation was done by using Fibra plus-FES-6 instrument**.** About 1g of the sample was weighed in the crucibles, fixed to the fibra plus instrument and then 100ml of 1.25% H_2SO_4 was added to all the samples by closing the knobs. The temperature was set to 370˚C and leave the sample for 40 minutes. After 40 minutes the temperature was reduced to 200˚C and open the knobs to remove all H_2SO_4 by suctioning and washed with distilled water by suctioning and the same procedure was repeated by adding of 100ml of 1.25% NaOH to all the samples. Then crucibles was taken and kept in an oven at 100˚C for 3 hours and the crucibles were cooled in desiccator and weight was taken (W_1). After weighing crucibles were kept in a muffle furnace at 500˚C for 1 hour, allowed to cool and reweighed (W_2). Per cent of crude fibre in the noodles was calculated by using the following formula:

$$\text{Crude fibre (\%)} = \frac{W_1 \text{ (g)} - W_2 \text{ (g)}}{\text{Weight of the sample (g)}} \text{ x } 100$$

Where,

W_1 = Weight of crucibles after drying in an oven

W_2 = Weight of crucibles after ashing in muffle furnace

Fat (%)

Fat content was determined by using the Socs plus-SCS-6 AS instrument as described by Ojure and Quadri (2012). Initially weight of the beaker was taken (initial weight) and two grams of the noodle samples were taken in thimbles and place the thimbles in thimble holder and keep the thimble holder in a beaker and to this 80 ml petroleum ether was added. The fat extraction process was carried out for 45 minutes by setting the temperature at 90˚C. After 40minutes the beakers were kept in an oven at 100˚C for 10-15 minutes to evaporate the petroleum ether. The beakers were then cooled in a desiccator and weighed again (final weight). The fat content was calculated using the following formula:

$$\text{Fat content (\%)} = \frac{\text{Final Weight (g) - Initial weight (g)}}{\text{Weight of the sample (g)}} \text{ x } 100$$

Ash (%)

Total ash content was determined by burning the noodles in pre-weighed crucible in a muffle furnace at 500°C for 6 hours (Rao and Bingren, 2009). After burning the residue ash weight was recorded and ash content was calculated by using the formula

$$\text{Total ash (\%)} = \frac{\text{Weight of the ash (g)}}{\text{Weight of the sample (g)}} \times 100$$

Peroxide value (meq/kg)

One gram of oil or fat from noodles was extracted by boiling in test tubes to this one gram of powdered potassium iodide and 20ml of solvent mixture was added. Transferred the contents to a conical flask containing 20ml of 5% potassium iodide solution, then to this 25ml of distilled water was added. The mixture was titrated against N/500 sodium thiosulphate solution until yellow colour was almost disappeared then again 0.5ml of starch was added and titrated till the blue colour disappeared.

$$\text{Peroxide value (meq/kg)} = \frac{\text{S x N x 1000}}{\text{Weight of sample taken}}$$

Where,

S = ml $Na_2S_2O_3$ (Test blank)

N = Normality of $Na_2S_2O_3$

ß-carotene (µg/g)

ß-carotene content was determined by soaking 5 g sample in 15 ml of AR grade acetone for 2hrs at room temperature under dark condition in order to get complete carotene extraction. The carotene layer was separated using petroleum ether through separating funnel. The volume was made up to 100 ml with petroleum ether and then this layer was again passed through sodium sulphate over the funnel in order to remove moisture from the layer. The optical density of the layer was measured at 452 nm using petroleum ether as blank (Srivastava and Kumar, 2002).

$$\text{ß-carotene (µg/g)} = \frac{\text{O. D x 13.9 x } 10^4 \text{ x 100}}{\text{Weight of the sample x 560 x 1000}}$$

Results of incorporation of drumstick leaf powder and defatted soybean flour on quality of instant noodles during storage

Moisture (%)

The moisture content of any food material is of significance to shelf life, packaging and general acceptance. In the present study, the significant difference was found to exist in the mean moisture content of noodles. The mean moisture content of the treatments ranged from 5.09 to 7.76 per cent. Higher moisture content was recorded in T_1 (6.73-7.76%) and lowest moisture content was recorded in T_3 (5.09-5.92%) during storage of four months. Compared to T_1 the mean moisture content was low in T_3 (Table 2) during all the months of storage. This might be due to incorporation of drumstick leaf powder which did not hold more water during storage. It is also possible that the low lipid content of drumstick leaf powder added noodles resulting in decreased water holding capacity when compared to wheat flour noodles. Low moisture content is important in the shelf life of noodles. Ritthiruangdej *et al.* (2011) reported that the moisture content of dried noodles decreased when the level of banana flour in the noodles was increased. These results are in agreement with Eyidemir and Hayta (2009) who reported that adding of apricot kernel flour (AKF) led to decrease in the moisture contents of noodles.

During storage the moisture content of both the treatments increased as the storage period enhanced. This might be due to packing of noodles in polythene cover which was not a good barrier and hence lead to absorption of moisture by the noodles during ambient storage.

Protein (%)

The perusal of data from Table 2 indicates that the mean protein content of the noodles varied between 11.45 to 17.13 per cent among the treatments and storage period. The highest protein content was recorded in the T_3 (17.23-16.92%) and it might be due to incorporation of defatted soybean flour and lowest protein content was recorded in T_1 (17.13-16.92%) (Fig. 1a.). These results are similar with Wani *et al.* (2013) who reported that the protein content (13.42) of noodles was increased with the incorporation of cauliflower leaf powder. Similar increase in protein content were also observed by Mridula *et al.* (2006) when noodles were incorporated defatted mustard flour (DMF). Ramu *et al*. (2016) observed that the protein content of spinach paste incorporated noodles increased from 11.56 per cent in control to 12.37 percent (20% spinach incorporation).

The mean protein content during 120 days of storage declined significantly from the initial level of 14.44 to 14.18 per cent which might be due to breakdown of amino acids (Premlatha *et al.*, 2010). Wani *et al.*, (2013) also observed that the mean crude protein content of noodles incorporated with cauliflower leaf powder declined significantly from the initial level of 13.01 to 12.97 per cent during 90 days of storage.

Crude fibre (%)

The data on crude fibre content of noodles are shown in Table 3. Mean crude fibre content was ranged from 0.28 to 1.34 among the treatments and storage period. Highest crude fibre content was recorded in T_3 (1.34-0.81 g/100g) and lowest was recorded in the T_1 (0.39-0.28g/100g) (Fig. 1b.). Even after 120 days of storage the treatment T_3 [RWF (73g)+ DLP (5g)+ DSF (10g)] recorded highest crude fibre content of 0.81 per cent than T_1 (0.28 %). Significant increase in crude fibre content was observed in drumstick leaf powder incorporated noodles as drumstick leaf powder is rich source of crude fibre when compared refined wheat flour. More crude fibre content was noticed in vegetable noodles possibly because of vegetables being rich in crude fiber (Ganiyu, 2005). Alcantara *et al*. (2013) reported that increase in the fibre content was observed in noodles added with taro powder which resulted from the removal of moisture during drying leading to increase in the concentration of fibre. Wani *et al.* (2013) reported that after 90 days of storage the treatment T_1 (100:00- whole wheat flour: cauliflower leaves) recorded the lowest crude fibre value of 3.28 per cent whereas treatment T_5 (80:20-malted wheat flour: cauliflower leaves) recorded maximum mean crude fibre content of 3.52 per cent.

Fat (%)

The data on fat content of noodles prepared from refined wheat flour alone and incorporation of drumstick leaf powder and defatted soybean flour are shown in Table 4. Significantly low-fat content was observed in drumstick leaf powder and defatted soybean flour incorporated noodles *i.e.*, T_3 (3.47- 4.59 %) when compared to control (4.41 -5.07) during storage period of four months (Fig. 1c.). Decreased trend in fat content was observed in both the treatments during storage period of four months. The decrease in fat content might be due to increase in the activity of lipase enzyme (lipolytic oxidation) during storage period. Similar results have been reported by Premalatha *et al*. (2010) in the development of wheat based high fibre noodles.

These results are in conformity to the results of Moss *et al*. (1987) and Park and Baik (2004) who suggested that lower fat content in noodles was due to a more compact structure as a result of strong adherence between protein and wheat starch as that found in instant noodles with higher protein content.

Ash (%)

Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents which provides the measure of total amount of minerals within the food (Shahnawaz *et al.,* 2009). In the present study significant difference was found to exist in the mean ash content of treatments. The highest ash content was recorded in T_3 (4.48-2.75%) and the lowest ash content was recorded in T_1 (2.91-2.00%) (Fig. 1d.). This might be due to incorporation of drumstick leaf powder in T_3 which is a rich source of minerals. Wani *et al.* (2013) observed that the noodles incorporated with 20 per cent cauliflower leaf powder recorded the highest value of 1.01 per cent 15 per cent cauliflower leaves with an ash content of 0.96 per cent.

During storage of four months the total mean ash content decreased from 2.91 to 2.00 per cent in control and 4.48 to 2.75 per cent in treatment T_3 (Table 4). Wani *et al.* (2013) also observed the decreased trend in ash content of cauliflower incorporated noodles during 90 days of storage period. The differences in the ash content of the samples were as a result of compositional differences (Omeire *et al.,* 2015).

Peroxide value (meq/kg)

The data on peroxide value of noodles are shown in Table 4. There was a significant difference observed between the treatments. Peroxide value ranged from 18.91meq/kg to 21.90

meq/kg. Lowest mean peroxide value was recorded in the T_3 (18.91-20.30 meq/kg) and highest was recorded in T_1 (21.08-21.90 meq/kg.) during the storage of four months. The lower peroxide value in T_3 might be due to low fat content of noodles as reported earlier from the present findings. The peroxide value showed increasing trend as the storage period advances in both the treatments. It may be due to oxidation reduction reaction. These results are in accordance with Holas and Kratochvil (1982) who reported that changes of lipids during storage of cereal products were for 0 days the peroxide value of cereal mixture was 25.7 meq/kg after 90 days it was found to be 34.6 meq/kg. Gotoh *et al.* (2007) reported that the changes in peroxide value (PV) in instant noodles stored at 40 to 60°C gradually increased and then rapidly increased after exceeding approximately 30 meq/kg, regardless of the oxidation temperature. This finding indicates that the peroxide value of 30 meq/kg is meaningful for suppressing the oxidation-induced formation of toxic compounds.

ß-carotene (µg/g)

Table 5 illustrates a general decrease in beta-carotene content occurred during storage period of 4 months. The highest value of ß-carotene content was observed in T_3 (1.73-1.38µg/g) and the minimum value was obtained in T_1 (0.48-0.42 µg/g). Incorporation of drumstick leaf powder which is a rich source of ß-carotene may enhance the ß-carotene content in T_3 noodles. These findings are similar to Wani *et al.* (2013), who reported that ß-carotene content was highest in cauliflower leaf powder incorporated noodles. Karnjanawipagul *et al.* (2010) showed that β-carotene content was higher in noodles supplemented with carrot flour and it varied from 1.02-7.11µg /100g. During storage, the ß-carotene content decreased in both the treatments from 0.46 to 0.42 µg/g and 1.73 to 1.38 µg/g in control and T_3, respectively. The decrease in ß-carotene content during storage might be due to the oxidative degradation of colour pigment (Potter, 1987).

Conclusions:

The noodles prepared by using drumstick leaf powder and defatted soybean flour show the greater variation between the treatments. The higher nutritional content was found in T_3 (73% Refined wheat flour + 5% Drumstick leaf powder + 10% Defatted soybean flour) compared to control T_1 during the 4 months of storage period. Use of 5 per cent drumstick leaf powder, 10 per cent defatted soybean flour along with other ingredients found to be better in increasing the nutrient density of the noodles.

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Table 1: Basic formulation of composite flour for instant noodles

Sl. No	Ingredients	Treatments						
		T_1	T_2	T_3	T_4	T_5	T_6	T_7
1	Refined wheat flour (g)	88.00	78.00	73.00	70.50	68.00	65.50	63.00
2	Drumstick leaf powder (g)	0	0	5.00	7.50	10.00	12.50	15.00
3	Defatted soybean flour (g)	0	10.00	10.00	10.00	10.00	10.00	10.00
4	Salt (g)	1.50	1.50	1.50	1.50	1.50	1.50	1.50
5	Starch (g)	5.00	5.00	5.00	5.00	5.00	5.00	5.00
6	Citric acid (g)	0.10	0.10	0.10	0.10	0.10	0.10	0.10
7	Potassium carbonate (g)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
8	Sodium carbonate (g)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
9	Edible vegetable oil(Ground nut) (g)	5.00	5.00	5.00	5.00	5.00	5.00	5.00
10	Guar gum (g)	0.30	0.30	0.30	0.30	0.30	0.30	0.30
11	Water (ml)	31.00	31.00	31.00	31.00	31.00	31.00	31.00

Table 2: Effect of storage period on moisture and protein content of nutri densed noodles

Treatments	Moisture (%)				Protein (%)			
	1 M	**2 M**	**3 M**	**4 M**	**1 M**	**2 M**	**3 M**	**4 M**
T_1 : RWF (88g)+ DLP (0g)+ DSF (0g)	6.73	6.86	7.22	7.76	11.76	11.66	11.53	11.45
T_3 : RWF (73g)+ DLP (5g)+ DSF (10g)	5.09	5.27	5.75	5.92	17.13	17.11	17.04	16.92
Mean	**5.91**	**6.06**	**6.48**	**6.84**	**14.44**	**14.39**	**14.28**	**14.18**
SD	0.80	0.50	0.34	0.13	0.40	0.71	0.47	0.56
t-value	3.76*	7.65*	7.21*	8.38*	33.41*	18.73*	19.21*	22.56*
% increase/decrease over control	24.36	23.17	20.36	23.71	45.66	46.74	47.78	47.77

* Significant at 1% of level SD: Standard Deviation M: Month

RWF: Refined Wheat Flour DLP: Drumstick Leaf Powder DSF: Defatted Soybean Flour

Common ingredients used in both the treatments

1. Salt (1.5g)
2. Starch (5g)
3. Citric acid (0.10g)
4. Potassium carbonate (0.05g)
5. Sodium carbonate (0.05g)
6. Edible vegetable(Groundnut) oil (5g)
7. Guar gum (0.3g)
8. Water (31ml)

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Table 3: Effect of storage period on crude fibre and fat content of nutri densed noodles

Treatments	Crude fibre (%)				Fat (%)			
	1 M	**2 M**	**3 M**	**4 M**	**1 M**	**2 M**	**3 M**	**4 M**
T_1: RWF (88g)+ DLP (0g)+ DSF (0g)	0.39	0.38	0.32	0.28	5.07	5.05	4.59	4.41
T_3: RWF (73g)+ DLP (5g)+ DSF (10g)	1.34	1.31	0.97	0.81	4.59	4.56	4.01	3.47
Mean	**0.86**	**0.85**	**0.65**	**0.54**	**4.83**	**4.81**	**4.30**	**3.94**
SD	0.22	0.03	0.21	0.07	0.10	0.16	0.47	0.44
t-value	12.63*	11.03*	9.36*	13.36*	5.78*	5.59*	3.123*	4.42*
% increase/decrease over control	5.22	4.97	3.10	2.26	9.46	9.70	12.63	21.31

* Significant at 1% of level SD: Standard Deviation M: Month

RWF: Refined Wheat Flour DLP: Drumstick Leaf Powder DSF: Defatted Soybean Flour

Common ingredients used in both the treatments

1. Salt (1.5g)
2. Starch (5g)
3. Citric acid (0.10g)
4. Potassium carbonate (0.05g)
5. Sodium carbonate (0.05g)
6. Edible vegetable(Groundnut) oil (5g)
7. Guar gum (0.3g)
8. Water (31ml)

Table 4: Effect of storage period on ash and peroxide value of nutri densed noodles

Treatments	Ash (%)				Peroxide value (meq/kg)			
	1 M	**2 M**	**3 M**	**4 M**	**1 M**	**2 M**	**3 M**	**4 M**
T_1: RWF (88g)+ DLP (0g)+ DSF (0g)	2.91	2.40	2.07	2.00	21.08	21.32	21.50	21.90
T_3: RWF (73g)+ DLP (5g)+ DSF (10g)	4.48	4.05	3.34	2.75	18.91	19.44	19.63	20.30
Mean	**3.69**	**3.23**	**2.70**	**2.37**	**19.99**	**20.38**	**20.56**	**21.10**
SD	0.29	0.23	0.13	0.56	0.50	0.45	0.48	1.25
t-value	16.26*	12.09*	23.22*	3.75*	8.51*	7.67*	7.46*	3.48
% increase/decrease over control	53.95	68.75	61.35	37.50	10.29	8.81	8.69	7.30

* Significant at 1% of level SD: Standard Deviation M: Month

RWF: Refined Wheat Flour DLP: Drumstick Leaf Powder DSF: Defatted Soybean Flour

Common ingredients used in both the treatments

1. Salt (1.5g) 2. Starch (5g) 3. Citric acid (0.10g) 4. Potassium carbonate (0.05g)
5. Sodium carbonate (0.05g) 6. Edible vegetable(Groundnut) oil (5g) 7. Guar gum (0.3g) 8. Water (31ml)

Table 5: Effect of storage period on ß-carotene of nutri densed noodles

Treatments	ß-carotene (µg/g)			
	1 Month	**2 Month**	**3 Month**	**4 Month**
T_1: RWF (88g) + DLP (0g) + DSF (0g)	0.48	0.46	0.44	0.42
T_3: RWF (73g) + DLP (5g) + DSF (10g)	1.73	1.72	1.63	1.38
Mean	**1.10**	**1.09**	**1.03**	**0.90**
SD	0.01	0.02	0.17	0.18
t-value	19.22*	17.88*	18.53*	14.62*
% increase/decrease over control	8.30	7.91	7.17	5.79

* Significant at 1% of level SD: Standard Deviation

RWF: Refined Wheat Flour DLP: Drumstick Leaf Powder DSF: Defatted Soybean Flour

Common ingredients used in both the treatments

1. Salt (1.5g) 2. Starch (5g) 3. Citric acid (0.10g) 4. Potassium carbonate (0.05g)
5. Sodium carbonate (0.05g) 6. Edible vegetable(Groundnut) oil (5g) 7. Guar gum (0.3g) 8. Water (31ml)

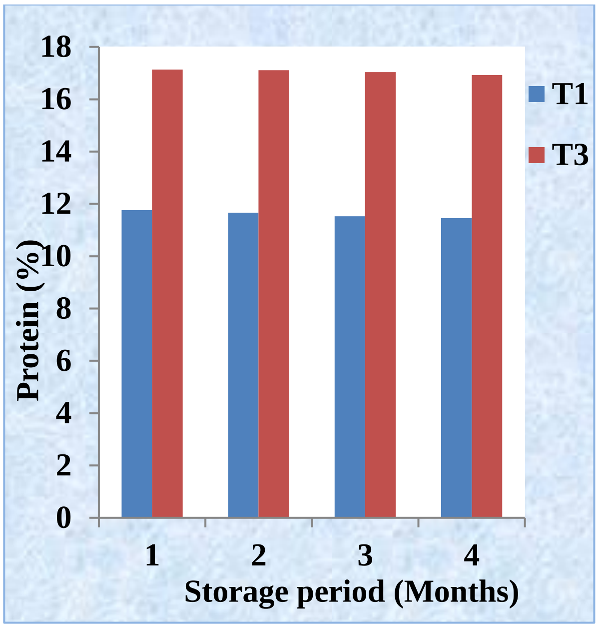

Figure 1a: Effect of storage period on protein content content of nutri densed noodles

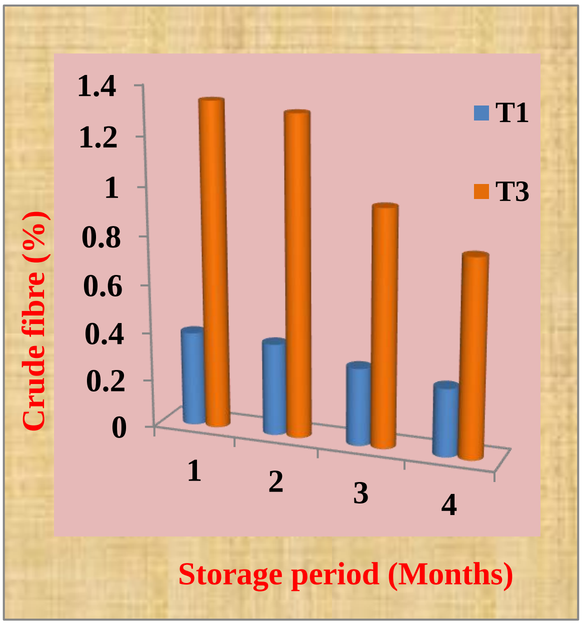

Figure 1b: Effect of storage period on of crude fibre content of nutri densed

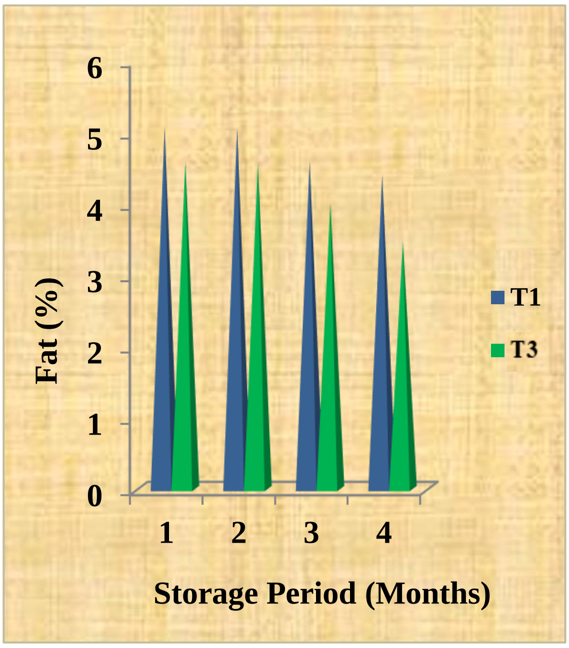

Figure 1c: Effect of storage period on fat content of nutri densed noodles

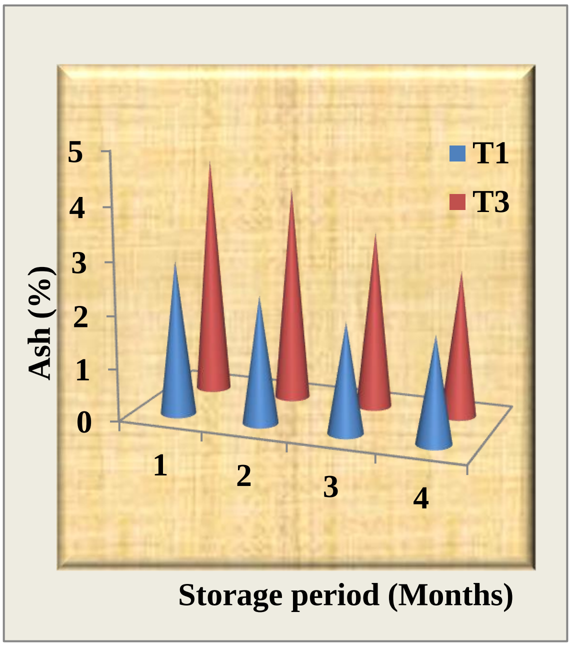

Figure 1d: Effect of storage period on ash content of nutri densed noodles

References:

1. Alcantara, R. M., Hurtada, W. A. and Dizon, E. I. (2013). The nutritional value and phytochemical components of taro (*colocasia esculenta*) powder and its selected processed foods. *J. Nutri. Food Scie*, 3(3):1-7.
2. Amaglo, N. K., Bennett, R. N., Lo Curto, R. B., Rosa, E. A. S., Lo Turco, V., Giuffrid, A., Lo Curto, A., Crea F and Timpo, G. M. (2010). Profiling selected phytochemicals and

nutrients in different tissues of the multipurpose tree *Moringa oleifera* L., grown in Ghana. Food Chem, 122:1047–1054.

3. Anonymous (1995). Approved Methods of the American Association of Cereal Chemists: Method 44-15A (9 ed.). St. Paul, MN; The Association.Engineering, 110(4):525–531.
4. Eyidemir, E. and Hayta, M. (2009). The effect of apricot kernel flour incorporation on the physicochemical and sensory properties of noodle. *African J. Biotech*., 8(1):085-090.
5. Fu, B. X. (2008). Asian noodles: History, classification, raw materials and processing. Food Research International 41:888-890.
6. Ganiyu, O. (2005). Nutritional and safety evaluation of some tropical green leafy vegetables. *J. Food Tech*., 3(3):389-392.
7. Gotoh, N., Iwasawa, A., Watanabe, H., Osato, R. and Wada, S. (2007). Oxidation of fats and oils in instant noodles stored under various conditions. Food Lipids, 14(4):350-365.
8. Gowrishankar, R., Kumar, M., Menon V., Divi, S. M., Saravanan, M., Magudapathy P., Panigrahi, B. K., Nair, K. G. and Venkataramaniah K. (2010). Trace element studies on *Tinospora cordifolia* (Menispermaceae), *Ocimum sanctum* (Lamiaceae), *Moringa oleifera* (Moringaceae) and *Phyllanthus niruri* (Euphorbiaceae) using PIXE. Biological Trace Element Research, 133:357–363.
9. Holas, J. and Kratochvil, J. (1982). Progress in cereal chemistry and technology, Research Institute of Flour-Milling and Baking Industries, Prague.
10. Hou, G. and Kruk, M. (1998). Asian noodle technology, Technical Bulletin 20:10.
11. Karnjanawipagul, P., Nittayanuntawech, W., Rojsanga, P. and Suntornsuk, L. (2010). Analysis of beeta-carotene in carrot by spectrophotometry. *J. Pharma. Scie.,* 37(1-2):8-16.
12. Khalid, B., Vidhu, A. andLubna, M. (2012). Physio-chemical and sensory characteristics of pasta fortified with chickpea flour and defatted soyflour. *J. Envt Sci. Toxicol and Food Tech*., 1:34-39.
13. Kumar, P. S., Mishra, D., Ghosh G. and Panda, G. S. (2010). Medicinal uses and pharmacological properties of *Moringa oleifera*. *Int. J. Phyto*., 2:210–216.
14. Li, M., Luo, L. J., Zhu, K. X., Guo, X. N., Peng, W. and Zhou, H. M. (2012). Effect of vacuum mixing on the quality characteristics of fresh noodles. *J. Food Eng*., 110(4):525–531.
15. Moss, R., Gore, P. J. and Murray, I. C. (1987). The influence of ingredients and processing variables on the quality and microstructure of Hokkien, Cantonese and instant noodles. Food Microstructure, 6:63-74.
16. Mridula, D., Tyagi, S. K. and Wanjari, O. D. (2006). Effect of defatted mustard flour on quality of noodles. *Indian J. Nutri. Dietary*, 43:305-311.

17. Ojure, M. A. and Quadri, J.A. (2012). Quality evaluation of noodles produced from unripe plantain flour using xanthan gum. *Int. J. Recent Res Appl Studies,* 13(3):740-752.
18. Omeire, G.C., Kabuo, N.O., Nwosu, J.N., Peter-Ikechukwu, A. and Nwosu, M.O. (2015). Enrichment of wheat or cassava noodles with partially defatted protein rich flours. *J. Envi Scie. Toxicol and Food Tech.,* 9(5):121-125.
19. Owen, G. (2001). Cereal processing technology. Cambridge: Woodhead Publishing.Panse, V. G. and Sukhatme, P. V. 1989.
20. Park, C. S. and Baik, B. K. 2004. Significance of amylose content of wheat starch on processing and textural properties of instant noodles. *Cereal Chem*., 81(4):521-526.
21. Potter, N.N. (1987). Food Science, CBS Publishers and Distributers, New Delhi. P. 72-79.
22. Premlatha, M. R., Jothilakskmi, K. and Kamalasundari, S. (2010). Development of wheat based high fibre khakra and noodles. Beverages and Food World, 24, 54-56.
23. Ramu, L., Jyotikiran, Maloo, S. and Ramugolla, 2016. Physical, chemical and sensory properties of spinach paste fortified instant noodles. *Int. J. Inn.Tech. Res*., 4(6):5318-5322.
24. Rao, Y. and Bingren, X. (2009). Determination of total ash and acid insoluble ash by NIS. The Pharma Social Japan, 129:881-886.
25. Ritthiruangdej, P., Parnbankled, S., Donchedee, S. and Wongsagonsup, R. (2011). Physical, chemical, textural and sensory properties of dried wheat noodles supplemented with unripe banana flour. *J. Natural Scie*., 45:500-509.
26. Shahnawaz, M., Sheikh S. A. and Nizamani, S. M. (2009). Determination of nutritive values of jamun fruit (*Eugenia jambolana*) products. *Pakistan J. Nutri*., 8:1275-1280.
27. Srivastava, R.P. and Kumar. (2002). *Fruit and Vegetable Preservation; Principles and Practices.* International Book Distributing Co. Lucknow, U.P, India. P. 64-98.
28. Wani, T. A., Sood, M., Amin, Q. A., Wani, N. and Kour H. (2013). Nutritional and organoleptic evaluation of noodles prepared by supplementation with cauliflower leaves. *Asian J. Horti*., 8(1), 304-312.

BREEDING STRATEGIES FOR DISEASE MANAGEMENT IN AGRICULTURE

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Abstract:

Disease management is a critical aspect of modern agricultural practices, influencing crop productivity, food security, and economic sustainability. Breeding for disease resistance offers a sustainable approach to combat plant pathogens, reducing the reliance on chemical inputs and minimizing environmental impacts. This paper provides an overview of the importance of disease resistance in agriculture and discusses the genetic basis of disease resistance, highlighting key mechanisms such as recognition and defense mechanisms, resistance genes, and quantitative disease resistance. Breeding strategies for disease resistance, including conventional breeding, marker-assisted selection, genetic engineering, and genome editing, are discussed in detail. Additionally, strategies for enhancing genetic diversity for disease resistance, such as utilizing wild germplasm and employing advanced breeding techniques, are explored. The paper concludes with future directions and challenges in breeding for disease management, emphasizing opportunities for leveraging genomic technologies, addressing socio-economic barriers, and fostering global collaboration. Ultimately, breeding for disease resistance holds immense potential in ensuring agricultural sustainability and food security in the face of evolving pathogen populations and changing environmental conditions.

Introduction:

Breeding for disease resistance is an effective and environmentally friendly approach to combat plant diseases. Disease outbreaks pose significant threats to global food production and agricultural sustainability. Plant diseases cause significant losses in crop yield and quality, affecting the livelihoods of millions of farmers worldwide. Diseases can spread rapidly under favorable environmental conditions, leading to widespread crop failures and food shortages. Economic impacts of plant diseases include reduced marketable yields, increased production costs due to disease management measures, and losses in export revenues. Plant diseases also have ecological consequences, disrupting natural ecosystems and biodiversity. With increasing concerns over environmental degradation, pesticide resistance, and food safety, there is a growing emphasis on developing resilient crop varieties with built-in disease resistance. Breeding for disease management presents a proactive and sustainable solution to mitigate the impacts of plant pathogens on agricultural systems. Breeding for disease resistance is a sustainable and cost-effective approach to managing plant diseases. Disease-resistant crop varieties offer built-in protection against pathogens, reducing the need for chemical pesticides and minimizing environmental risks. Resistant varieties can contribute to increased crop productivity, improved food quality, and enhanced farmer income. Breeding for disease resistance is crucial for ensuring long-term food security and resilience in the face of evolving pathogen populations and changing climatic conditions.

1. Importance of disease resistance in agriculture:

Disease resistance in agriculture is of paramount importance due to its multifaceted impacts on crop productivity, economic stability, and environmental sustainability.

(a) Maintaining crop health and productivity: Disease-resistant crop varieties help maintain the health and vigor of plants by reducing their susceptibility to pathogens. This resistance minimizes the incidence and severity of diseases, allowing crops to thrive and reach their full yield potential. As a result, farmers can achieve higher productivity and profitability, contributing to food security and economic growth.

(b) Reducing crop losses: Plant diseases can cause significant yield losses, ranging from partial to complete crop failure, depending on the severity of the infection and the susceptibility of the cultivar. Disease-resistant varieties provide a crucial defense against such losses by limiting the spread and impact of pathogens. By minimizing crop losses, disease resistance helps stabilize food production and supply, particularly in regions prone to endemic diseases or unpredictable environmental conditions.

(c) Decreasing dependency on chemical inputs: Conventional disease management often relies on the application of chemical pesticides and fungicides, which can have adverse effects on human health, non-target organisms, and the environment. Disease-resistant crops offer a sustainable alternative by reducing the need for synthetic chemicals. This not only mitigates environmental pollution but also minimizes production costs and labor inputs associated with pesticide application, thereby promoting ecological balance and resource efficiency in agriculture.

(d) Enhancing environmental sustainability: Disease-resistant crops contribute to the overall sustainability of agricultural systems by reducing the environmental footprint of farming practices. By requiring fewer chemical inputs and fostering biological control mechanisms, they help preserve soil health, water quality, and biodiversity. Moreover, the adoption of disease-resistant varieties can support the transition towards more regenerative and climate-resilient agricultural systems, thereby mitigating the adverse impacts of climate change on food production.

(e) Facilitating Integrated Pest Management (IPM): Disease resistance complements other components of integrated pest management (IPM), such as cultural practices, biological control, and monitoring systems. By incorporating disease-resistant cultivars into IPM strategies, farmers can implement holistic approaches to pest and disease management that are effective, environmentally friendly, and economically viable. This integrated approach maximizes the resilience of agroecosystems and reduces the risks of pest and disease outbreaks over the long term.

2. Genetic basis of disease resistance: The genetic basis of disease resistance in plants is a complex and multifaceted phenomenon involving various genetic mechanisms and interactions between the host plant and the pathogen. Understanding these genetic foundations is crucial for developing effective breeding strategies to enhance disease resistance in crop plants. Here are some key aspects of the genetic basis of disease resistance.

(a) Recognition and defense mechanism: Plants possess innate immune systems that enable them to recognize and respond to pathogen attack. This recognition often involves the detection of conserved molecular patterns associated with pathogens, known as pathogen-associated molecular patterns (PAMPs), by plant pattern recognition receptors (PRRs). Upon recognition, plants activate a cascade of defense responses, including the production of antimicrobial compounds, reinforcement of cell walls, and induction of programmed cell death (hypersensitive response) to restrict pathogen spread.

(b) Resistance (R) genes: Resistance genes, also known as R genes, play a central role in plant immunity by directly or indirectly recognizing specific pathogen effectors, proteins secreted by pathogens to manipulate host defenses. R genes typically encode intracellular receptors belonging to diverse protein families, such as nucleotide-binding site leucine-rich repeat (NBS-LRR) proteins, receptor-like kinases (RLKs), and receptor-like proteins (RLPs). Upon effect or recognition, R genes trigger immune signaling pathways leading to the activation of defense responses.

(c) Gene-for gene hypothesis: The gene-for-gene hypothesis, proposed by Harold Flor in the 1940s, provides a conceptual framework for understanding the interactions between plant resistance genes and pathogen effectors. According to this hypothesis, resistance in the plant (controlled by R genes) is effective only if the corresponding avirulence gene (Avr gene) is present in the pathogen. The interaction between specific R and Avr gene pairs results in the activation of defense responses and the inhibition of pathogen growth, leading to resistance.

(d) Quantitative disease resistance: In addition to major resistance genes (qualitative resistance), plants also exhibit quantitative disease resistance, which involves the cumulative effect of multiple genes with small individual effects. Quantitative resistance is typically controlled by quantitative trait loci (QTLs) distributed throughout the plant genome. These loci contribute to the overall resistance phenotype by modulating various aspects of the host-pathogen interaction, such as pathogen recognition, signal transduction, and defense activation.

(e) Genetic diversity and evolutionary dynamics: The genetic basis of disease resistance is shaped by evolutionary processes, including natural selection, genetic drift, and gene flow.

Pathogens continuously evolve to overcome host resistance mechanisms, leading to the emergence of new pathogen variants and the breakdown of resistance in previously resistant cultivars. Consequently, maintaining genetic diversity in crop populations and deploying diverse sources of resistance are essential strategies for sustainable disease management.

In conclusion, the genetic basis of disease resistance in plants involves a complex interplay between host and pathogen genomes, with multiple genetic mechanisms contributing to resistance. Harnessing this genetic diversity through breeding and biotechnological approaches offers promising avenues for developing durable and sustainable disease-resistant crop varieties to ensure global food security.

3. Breeding strategies for disease resistance:

Breeding for disease resistance in crop plants involves the strategic selection and development of cultivars with enhanced resistance to pathogens. Various breeding strategies and techniques are employed to achieve this goal, each tailored to the specific characteristics of the target crop and the pathogens it faces. Here are some key breeding strategies for disease resistance:

(a) Conventional breeding:

Phenotypic selection: Traditional breeding methods rely on visual assessment of plant phenotypes for disease resistance. Resistant individuals are selected based on their performance in disease-challenged environments.

Cross breeding: Introducing genetic diversity through controlled crosses between different parental lines with desirable traits, including disease resistance, is a fundamental approach in conventional breeding.

Backcrossing: To transfer a specific resistance gene or trait from a wild or exotic donor into an elite cultivar, backcrossing is used. This technique involves repeatedly crossing the elite cultivar with the donor parent followed by backcrossing to the elite parent to recover its desired characteristics while retaining the introduced trait.

(b) Marker-Assisted Selection (MAS):

Molecular markers: MAS enables the indirect selection of desired traits, including disease resistance, based on the presence or absence of molecular markers linked to specific genomic regions associated with resistance genes or quantitative trait loci (QTLs).

Genomic selection: Utilizing genome-wide marker data to predict the breeding value of individuals, genomic selection facilitates the simultaneous selection of multiple traits, including disease resistance, thereby accelerating the breeding process.

(c) Genetic engineering: Genetic engineering techniques, such as gene insertion or gene editing, are used to introduce or modify specific genes associated with disease resistance into crop plants.

This approach allows for precise manipulation of plant genomes to enhance resistance against target pathogens

Transgenic approach: Genetic engineering techniques, such as gene insertion or gene editing, are used to introduce or modify specific genes associated with disease resistance into crop plants. This approach allows for precise manipulation of plant genomes to enhance resistance against target pathogens.

RNA interference (RNAi): RNAi-mediated gene silencing can be employed to suppress the expression of genes essential for pathogen virulence, thereby conferring resistance to specific diseases without introducing foreign DNA.

(d) Genome editing:

CRISPR/Cas9: The CRISPR/Cas9 system enables precise genome editing by inducing targeted DNA modifications. This technology can be utilized to introduce mutations or deletions in genes associated with susceptibility to pathogens, resulting in enhanced resistance in crop plants.

(e) Pyramiding resistance genes: Combining multiple resistance genes or QTLs into a single cultivar through pyramiding can enhance the durability and broad-spectrum resistance of the resulting varieties. This strategy reduces the risk of pathogen adaptation and breakdown of resistance over time.

(e) Marker-assisted introgression: Incorporating resistance genes or QTLs from wild or exotic germplasm into elite cultivars using marker-assisted introgression allows breeders to exploit genetic diversity for disease resistance while minimizing linkage drag and maintaining desirable agronomic traits.

4. Enhancing genetic diversity for disease resistance: Enhancing genetic diversity for disease resistance is crucial for developing resilient crop varieties capable of withstanding evolving pathogen populations and changing environmental conditions. Here are several strategies to achieve this:

(a) Utilizing wild and exotic germplasm: Wild relatives and exotic germplasm often harbor unique alleles for disease resistance that are absent in cultivated varieties. Introducing genetic diversity from these sources through hybridization and introgression can enrich the gene pool and broaden the spectrum of resistance in crop plants.

(b) Exploring landraces and traditional varieties: Landraces and traditional varieties cultivated by indigenous communities often exhibit a rich diversity of traits, including disease resistance. Preservation and characterization of these genetic resources can provide valuable reservoirs of diversity for breeding programs seeking to enhance disease resistance.

(c) Genetic diversity, panels and germplasm collections: Establishing and maintaining diverse germplasm collections and genetic diversity panels allows breeders to access a wide range of genetic variation for disease resistance. Systematic evaluation of these resources under different disease pressure can identify promising candidates for further breeding efforts.

(d) Hybridization and cross breeding: Controlled crosses between genetically diverse parental lines facilitate recombination and segregation of alleles, leading to the generation of novel genetic combinations. Hybridization programs aimed at maximizing genetic diversity can produce progeny with enhanced disease resistance due to heterosis or hybrid vigor.

(e) Mutation breeding: Inducing genetic variation through mutagenesis techniques, such as chemical mutagenesis or irradiation, can create novel alleles for disease resistance. Screening mutant populations for resistance phenotypes followed by selection and breeding of desirable mutants can contribute to genetic diversity enhancement.

(f) Genome Wide Association Studies (GWAS): GWAS involves analyzing genetic variation across diverse populations to identify genomic regions associated with disease resistance traits. Understanding the genetic architecture of resistance allows breeders to target specific loci for introgression or marker-assisted selection, thereby enhancing genetic diversity while improving disease resistance.

(g) In silico approaches: Computational methods, such as genomics-assisted breeding and bioinformatics analysis, enable the exploration of genetic diversity through virtual screening of diverse germplasm collections and prediction of novel candidate genes for disease resistance. Integrating in silico approaches with traditional breeding methods accelerates the identification and utilization of genetic diversity for improved disease resistance.

In conclusion, enhancing genetic diversity for disease resistance involves a multidimensional approach encompassing the exploration of diverse genetic resources, the utilization of advanced breeding techniques, and the integration of genomic tools and computational methods. By harnessing the full spectrum of genetic variation available in crop plants, breeders can develop resilient varieties capable of effectively combating plant diseases and ensuring sustainable agricultural production.

Future directions and challenges:

- Opportunities for leveraging advances in genomics, bioinformatics, and phenotyping technologies for accelerating breeding for disease resistance.
- Addressing socio-economic and regulatory barriers to the adoption of disease-resistant varieties.
- Considerations for sustainable and equitable access to disease-resistant germplasm in developing countries.

1. Genomic revolution: The integration of genomic technologies such as high-throughput sequencing, genome editing, and bioinformatics will continue to revolutionize breeding for disease resistance. However, challenges include ethical considerations surrounding genome editing, managing vast amounts of genomic data, and ensuring equitable access to advanced technologies.

2. Multi-omics approaches: Embracing multi-omics techniques (genomics, transcriptomics, proteomics and metabolomics) offers comprehensive insights into plant-pathogen interactions. Challenges include data integration, standardization of methodologies, and deciphering complex biological networks

3. Enhancing host-plant immunity: Future strategies may focus on engineering plants with improved defense signaling pathways and inducible resistance mechanisms. Balancing defense activation with growth trade-offs and addressing potential ecological impacts are significant challenges.

4. Mining natural geneetic variation: Exploring wild and exotic germplasm for novel resistance alleles remains crucial. Overcoming challenges such as genetic incompatibility, linkage drag, and regulatory constraints is essential for successful introgression of resistance traits into elite cultivars.

5. Engineering durable resistance: Pyramiding multiple resistance genes or QTLs is essential for conferring durable and broad-spectrum resistance. Identifying complementary resistance genes and managing trade-offs between resistance and other agronomic traits pose significant challenges.

6. Climate resilience: Breeding for disease resistance in the context of climate change and emerging environmental challenges is critical. Developing varieties with tolerance to abiotic stresses such as drought, heat, and salinity will enhance overall resilience. However, uncertainties in climate projections and genotype-by-environment interactions present challenges.

7. Socio-economic considerations: Addressing socio-economic factors influencing the adoption of disease-resistant varieties by farmers is essential. Ensuring equitable access to improved germplasm and breeding technologies, along with farmer education and awareness, requires concerted efforts.

8. Global collaboration and capacity building: Strengthening international partnerships for sharing germplasm, knowledge, and resources is vital. Capacity building initiatives to enhance breeding expertise and infrastructure in developing countries are necessary, but challenges such as intellectual property rights and funding constraints persist.

Conclusion:

Breeding for disease management plays a crucial role in ensuring agricultural sustainability and food security in a changing climate. By harnessing genetic diversity and innovative breeding techniques, researchers and breeders can develop resilient crop varieties capable of withstanding emerging disease pressures. Collaboration between the public and private sectors, along with farmer engagement, is essential for translating scientific advancements into practical solutions that benefit both producers and consumers. Continued investment in breeding for disease resistance is paramount to addressing global challenges and building resilient food systems for the future.

References:

1. Agrios, G. N. (2005). Plant Pathology (5th ed.). Academic Press. ISBN: 978-0120445653.
2. Agrios, G. N. (2005). Plant Pathology (5th ed.). Academic Press. ISBN: 978-0120445653.
3. Cook, R. J., & Baker, K. F. (1983). The Nature and Practice of Biological Control of Plant Pathogens. American Phytopathological Society. ISBN: 978-0890540464.
4. Garrett, K. A., et al. (2009). Complexity in climate-change impacts: An analytical framework for effects mediated by plant disease. Plant Pathology, 58(1), 15-30. DOI: 10.1111/j.1365-3059.2008.01925.x.
5. Gnanamanickam, S. S. (Ed.). (2009). Plant-Associated Bacteria. Springer. ISBN: 978-1402080078.
6. Madden, L. V., Hughes, G., & Bosch, F. van den (Eds.). (2007). The Study of Plant Disease Epidemics. APS Press. ISBN: 978-0890543502.
7. Newton, A. C., & Johnson, S. N. (2011). Climate change and its effects on terrestrial insects and herbivory patterns. Insects, 2(2), 157-174. DOI: 10.3390/insects2020157.
8. Oerke, E. C., & Dehne, H. W. (2004). Safeguarding Production—Losses in Major Crops and the Role of Crop Protection. Crop Protection, 23(4), 275-285. DOI: 10.1016/j.cropro.2003.10.001.
9. Rossi, V., & Caffi, T. (2012). Spatially explicit simulation of plant disease epidemics: Needs, challenges, and perspectives. Plant Pathology, 61(1), 1-7. DOI: 10.1111/j.1365-3059.2011.02541-x.
10. Savary, S., Willocquet, L., Pethybridge, S. J., & Esker, P. (2011). The global burden of pathogens and pests on major food crops. Nature Ecology & Evolution, 3(3), 430-439. DOI: 10.1038/s41559-019-0793-y.
11. Strange, R. N., & Scott, P. R. (2005). Plant Disease: A Threat to Global Food Security. Annual Review of Phytopathology, 43, 83-116. DOI: 10.1146/annurev.phyto.43.113004.133839.
12. Thakur, R. P., & Heath, M. C. (1996). Mechanisms of Resistance to Plant Diseases. Springer. ISBN: 978-3540605683.
13. Wilson, C. L., & Wisniewski, M. E. (Eds.). (1994). Biological Control of Postharvest Diseases: Theory and Practice. CRC Press. ISBN: 978-0849388053.

RECENT ADVANCES IN SENSOR BASED IRRIGATION

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Abstract:

Recent technological advancements have introduced soil water sensors, transforming irrigation systems for improved efficiency. These sensors are pivotal in natural resource management, aiding in watershed management, environmental monitoring, and precision agriculture. By providing real-time soil moisture data, they enable growers to optimize irrigation, promoting water use efficiency and sustainable practices. However, selecting the appropriate sensor requires consideration of factors like application and soil type, vital as water scarcity becomes a pressing concern

Introduction:

The world's population has exceeded 7 billion and will continue to increase with a high rate. To feed the increasing population, our agriculture must produce more food. Irrigated agriculture accounts for 40 per cent of food production, and 70 per cent of fresh water withdrawals are used by irrigation. Irrigation is important for the food security of the world. Given climate change and increased groundwater pollution, we are facing a global water crisis and stronger constraints on water resources.

There is a great need to modernize agricultural practices for better water productivity and resource conservation. Efficient water management is a major concern in precision irrigation practices. The use of automated irrigation systems can provide water on a real-time basis at the root zone, based on the availability of soil water at the crop root zone, which also leads to saving of water. Although the majority of crops are grown with irrigation systems, drip and sprinkler irrigation are increasing in popularity because of superior water application efficiency and more precise irrigation management. Automated irrigation systems allow for high-frequency irrigation, thus maintaining the soil water potential (SWP) relatively constant, compared to conventional irrigation systems. Many methods have been described and sensors developed to manage irrigation systems effectively (Chaitra, 2019).

Irrigation: The artificial application of water to the soil for the purpose of crop production in supplement to rainfall and ground water contribution (Barkunan *et al.*, 2019).

- Management of water, based on the soil & crop environment to obtain better yield by efficient use of water without any effect to the environment.

- Problems & need of irrigation water logging and unavailability of water for plant growth and development.
- In current water availability status precision water management is important.

According to report submitted by International Water Management Institute (IMWI) from Sri lanka they projected water scarcity in their report.

- **Red colour indicates physical water scarcity:** Physical water scarcity can often occur when and where there is not enough water to meet both human demands and those of ecosystems to function effectively. Arid regions can constantly suffer from physical water scarcity. It also occurs where water seems abundant but resources are over-committed.
- **Yellow colour indicates economic water scarcity**: Economic water scarcity, is caused by a lack of investment in [water] infrastructure or insufficient human capacity to satisfy the demand of water in areas where the population cannot afford to use an adequate source of water.
- **Blue colour indicates no water scarcity:** Sufficient water present in the system

Table 1: Total water present on earth surface, 69 per cent of water is used for agriculture in world and 82 per cent of water is used for agriculture in India

Usage in (%)	World	India
Agriculture	69	82
Industry	23	12
Domestic use	8	6

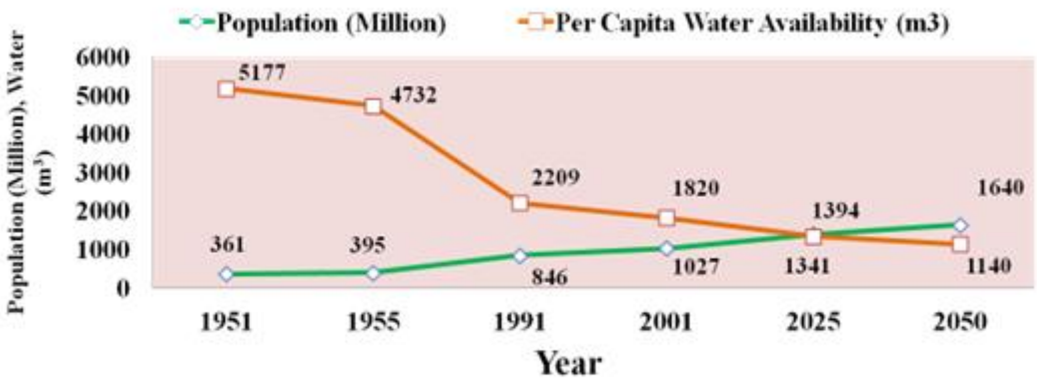


Figure 1: Trends and projection of population and per capita availability of water per year in India

Major issues of water

1. **Over exploitation of groundwater**
    - Ground water depletion most commonly occurs because of the frequent pumping of water from the ground.

- We contiously pump groundwater from aquifers and it does not have enough time to replenish itself.
- Agricultural needs require a large amount of ground water

2. **Increasing pollution / declining water quality**

- Water resources are unlimited.
- Water is available at no cost.
- More irrigation – more yield.
- Head-reach farmers-right to use any quantity of water.
- Underground aquifers supply limitless water.

Supply of irrigation water to the farmers is the duty of the Government. Groundwater pollution is a significant problem, intensified when storage is decreased. The most serious water quality degradation in agricultural regions is caused by fertilizer and pesticide use, which results in runoff of chemicals from agricultural fields into surface waters and percolation into groundwater.

3. Trans boundary water disputes: The transboundary water resources are surface water and ground water resources that cut cross political borders of states. Therefore, transboundary water conflicts are usually contentious, because it crosses three overlapping issues: natural resources, survival, and sovereignty.

4. Virtual water

- The virtual water concept, also known as embodied water, was coined by John Anthony Allan (Tony Allan) in 1993. He received the Stockholm Water Prize for this innovative concept late in 2009.
- Hoekstra has defined the virtual-water content of a product (a commodity, good or service) as the volume of freshwater used to produce the product, measured at the place where the product was actually produced. It refers to the sum of the water use in the various steps of the production chain.

5. Low canal irrigation efficiency

- Evaporation from the water surface
- Deep percolation to soil layers underneath the canals
- Seepage through the bunds of the canals
- Overtopping the bunds
- Bund breaks
- Runoff in the drain
- Rat holes in the canal bunds
- Declining tank performance
- Due to accumulation of silt in the tank can lead to reduction of tank performance.

With all these aspects under irrigated condition there is a need to improve the water productivity by increasing the conveyance, application and distribution efficiency to improve the yield and WUE with a concept of more crop per drop of water.

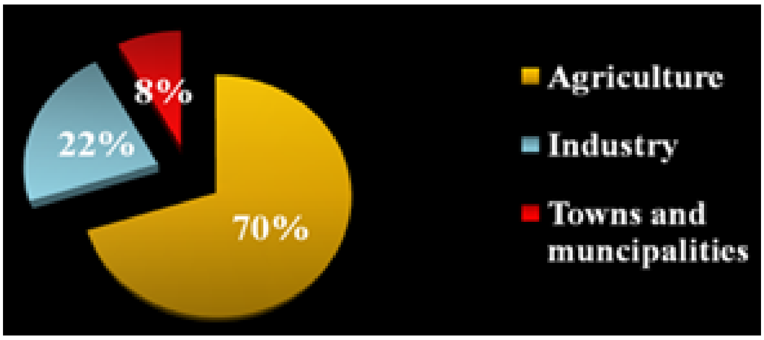


Figure 2: India's water usage in different sectors, agriculture about 7 %, industry 22% and others 8%, it leads to increase of water requirement of different sectors

Approaches for precision water management

- Micro irrigation system
- Variable rate irrigation
- Smart automated irrigation

Sensor

- Sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. ¬ Soil moisture sensors measure the water content in the soil.
- Soil moisture sensors measure some other property, such as electricalresistance, dielectric constant, or interaction with neutrons, as a proxy for moisture content.
- The World's soil moisture sensor market has been estimated to grow at a rate of 16.2% between 2015 and 2022 reaching sales of 206.2 million U.S. dollars.

Need of sensors

1. Production Efficiency

   Sensors are good source for monitoring spatial variation of soil moisture and it can be an effective tool for precisely managing for crop production.
2. Efficient input usages

   Judicious application of irrigation water according to sensor value data improve the efficiency of applied inputs. Sensors allow site specific crop managent practices which is essential present day agriculture.
3. Product quality

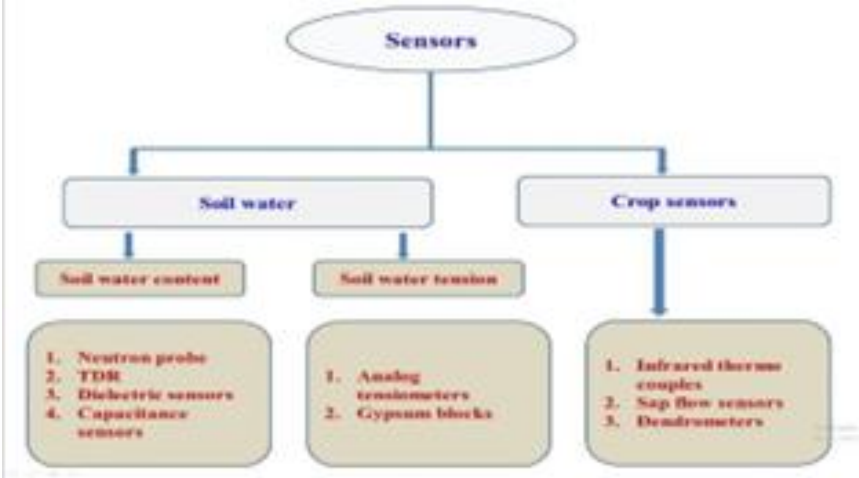
   Inclusion of sensor technology in agriculture increases the product quality
4. Soil & ground water protection

   Majority of the farmers are not following scientific methods of irrigation scheduling practices. That leads problems like water logging and wastage of precious water resource. As in present situation sensors in irrigation are important.

Sensors in Agricultural production

1. **Soil health assessment:** Soil organic carbon, Sodium absorption Ratio, pH, EC and microbial activity.
2. **Climate related:** Temperature, humidity, rain
3. **Soil management:** Gradient, soil profile changes,
4. **Nutrient management:** Time/ dose/ place of application
5. **Water management:** Moisture status of soil/ plant, time of irrigation, automation of irrigation, salinity/ water logging
6. **Disease management:** Forecasting, precise control,
7. **Insect management:** Surveillance, forecast, control
8. **Weed management:** Forecast, precise control
9. **Crop growth analysis:** Growth/ yield projections,
10. **Root growth:** Root biomass indicator
11. **Harvesting related:** Harvest time, monitoring yield variations
12. **Quality assessment**: Advance prediction of quality, quality management strategies.

Classification of sensors



Sensors in water management (Lathashree, 2018)

1. Ground water monitoring sensors

- Real time monitoring of ground water fluctuations
- Remote sensing based system

2. Irrigation water quality sensors

- pH sensor
- Electrical conductivity
- Turbidity sensor (Sediments)
- Chlorine Residual Sensor
- TOC Sensor - Total organic carbon (TOC)
- ORP Sensor - Oxygen-Reduction Potential

3. Plant based Sensors

- Chlorophyll Fluorescence Imaging Sensors (CFIS)
- Multispectral and Hyper-spectral imaging sensor
- Thermal Imaging (IRT) /Temperature sensor

4. Soil moisture sensors (Rafael *et al.*, 2005)

1. Tensiometric sensors
- Tensiometers
- Gypsum resistance blocks
2. Volumetric sensors
- Time domain reflectometry
- Frequency domain reflectometry
- Neutron moderation

1. Tensiometers

- Tensiometer is a sealed, airtight, water-filled tube (barrel) with a porous tip on one end and a vacuum gauge on the other.
- A tensiometer measures soil water suction (negative pressure), which is usually expressed as tension.
- This suction is equivalent to the force or energy that a plant must exert to extract water from the soil.
- The suction force in the porous tip is transmitted through the water column inside the tube and displayed as a tension reading on the vacuum gauge.
- Soil-water tension is commonly expressed in units of bars or centibars. One bar is equal to 100centibars (cb).
- As the suction approaches approximately 0.8 bar (80 cb), the cohesive forces are exceeded by the suction and the water molecules separate. When this occurs, air can enter the tube through the porus tip and the tensiometer no longer functions correctly. This condition is referred to as breaking tension.

2. Gypsum resistance blocks:

Resistance blocks work on the principle that water conducts electricity. When properly installed, the water suction of the porous block is in equilibrium with the soil-water suction of the surrounding soil. As the soil moisture changes, the water content of the porous block also changes. The electrical resistance between the two electrodes increases as the water content of the porous block decreases. The block's resistance can be related to the water content of the soil by a calibration curve.

3. Neutron probe

- Soil moisture can be estimated quickly and continuously with neutron moisture meter without disturbing the soil.

(ISBN: 978-93-95847-86-5)

- This meter scans the soil about 15 cm diameters around the neutron probe in wet soil and 50 cm in dry soil. Consists of a probe and a scalar or rate meter.
- This contains a fast neutron source which may be a mixture of radium and beryllium or americium and beryllium.
- Access tubes are aluminum tubes of 50-100 cm length and are placed in the field when the moisture has to be estimated.
- Neutron probe is lowered in to access tube to a desired depth. Fast neutrons are released from the probe which scatters in to soil.
- The scalar or the rate meter counts of slow neutrons which are directly proportional to water molecule.
- Moisture content of the soil can be known from the calibration curve with count of slow neutrons.

4. Soil moisture indicator:

Soil moisture indicator is a user friendly moisture indicating device which was developed by ICAR- Sugarcane Breeding Institute through 'farmers' participatory research.

- Soil moisture indicator is the sensor device measures the volumetric water content in the soil.
- It is used to measure the rise and fall of amount (percentage) of water in soil.
- Sensor rods inserted into the soil.
- Resistance between the sensor rods depends on moisture content in soil between the rods.

The electric circuit is designed in such a way to display moisture level by glowing any one coloured LED light (Durga *et al*.2018).

Time domain reflectometry: The time domain reflectometer (TDR) is a new device developed to measure soilwater content. Two parallel rods or stiff wires are inserted into the soil to the depth at which the average water content is desired. The rods are connected to an instrument that sends an electromagnetic pulse (or wave) of energy along the rods. The rate at which the wave of energy is conducted into the soil and reflected back to the soil surface is directly related to the average water content of the soil. One instrument can be used for hundreds of pairs of rods. This device, just becoming commercially available, is easy to use and reliable.

Frequency domain reflectometry: Capacitance can be measured from the change in frequency of a reflected radio wave or resonance frequency. The difference between the output wave and the return wave frequency is measured to determine soil moisture. FDR probes are considered accurate but must be calibrated for the type of soil they will be buried in. They offer a faster response time compared to Time Domain Reflectometer (TDR) probes. These sensors are often referred to as frequency domain reflectometers (FDR), however the term FDR is often misused because most frequency sensors are using a single frequency and not a domain of frequencies. Other capacitance probes and amplitude impedance-based probes are often mistakenly referred to as “FDRs”. The volume of measurement is dependent on sensor size with most sensors in the order of 5cm to 10cm in length but one sensor is 3m in length. The field of influence is greatest at the sensor to substrate interface and declines rapidly from there. Generally, the field of influence is approximately 1cm distance from the sensor. Given a 3m length sensor with 1cm distance into the surrounding medium, extreme caution needs to be taken with installation to ensure there are no air gaps.

Resistive and capacitive soil moisture sensors:

Resistive Soil Moisture Sensor: The sensor comprises two probes that measure the volumetric substance of water. The two probes send an electrical current into the ground, and the level of moisture is established by examining the resistance encountered by the current. When there is high moisture, the soil is more conductive and less resistant. Dry soil does not conduct electricity well, so when there is less moisture, the earth is more resistant and less conductive. The real issue with a resistive soil moisture sensor is corrosion of the probes because it causes inaccurate measurements due to electrolysis of the sensors.

Capacitive Soil Moisture Sensor: The capacitive moisture sensor estimates the soil moisture level with a capacitive sensing technique rather than a resistive one, and it is less susceptible to corrosion because it is made of more resistant material. The sensor incorporates a voltage controller that provides a working voltage scope of 3.3 ~ 5.5V. It is good with low-voltage MCUs (both 3.3V and 5V logic). For optimal performance with Raspberry Pi, an ADC converter is required. Capacitive probes are becoming increasingly popular, and they have several benefits. They do not corrode and provide more reliable results than resistance estimating.

Automation in irrigation: Automation is a kind of innovation, in which the manual interventions are replaced by an automated system to perform all the operations.

Automation in irrigation: It is a system by which all the operations related to the supply of irrigation water to the crop are carried out, automatically with no or minimum manual interventions. An automatic irrigation system that receives feedback from one or more soil moisture sensors is designed to maintain a desired range moisture in the root zone that is optimal for plant growth.

Need of automation irrigation

- A primary limitation to using ET-based systems is the lack of accurate crop coefficients which are necessary to calculate actual ET (Kati *et al.,* 2010)
- Automation eliminates manual operations
- Possibility to change frequency of irrigation and fertigation process and also to optimize these processes
- Increased water and fertilizer use efficiency
- Smooth and efficient system operation
- Optimizing energy requirements and increase yield

Advantages of sensors

- Increase in productivity
- Safe & No manpower required
- Reduce soil erosion& nutrient leaching
- Require smaller water source
- Efficient and Saves Time

Barriers of sensor based irrigation

- ❖ High power consumption of devices
- ❖ Hardware equipment is expressed to harsh environment condition
- ❖ Weak communication signals
- ❖ Reliable internet connection not available in all locations
- ❖ Lack of IoT knowledge & application of farmers
- ❖ Low security & privacy on devices and servers Short battery life for equipment.

Conclusion:

Water is a limited resource in the world and agriculture is a primary market. Therefore, a sustainable and economic approach is to be adopted for efficient agricultural practice and irrigation scheduling. The use of soil moisture sensors helps growers with irrigation scheduling by providing information about when to water the crops. The advantages and disadvantages of sensors must be considered as criteria for selection because the working principle behind each type of sensor varies with its application and type of soil.

References:

1. Barkunan, S. R., Bhanumathi, V. and Sethuram, J., (2019). Smart sensor for automatic drip irrigation system for paddy cultivation. Comptures Electric. Engineer.,73:180-193.
2. Chaitra (2019). Sensor based irrigation management in Rice (*Oryza sativa* L.), M.Sc (Agri.) Thesis, submitted to *Univ. Agric. Sci., Bengaluru.*
3. Durga, C. V., Ramulu, M., Umadevi and Suresh, K. (2018). Evaluation of soil moisture sensors and irrigation scheduling in rabi maize (*Zea mays* L.). Int. J. Chem. Stud., 6(5): 1789-1792.
4. Lathashree, A. V. (2018). Sensor based irrigation management in Rice (*Oryza sativa* L.), M. Sc. (Agri.) Thesis, submitted to Univ. Agric. Sci., Bengaluru.
5. Rafael, M. C., Michael, D. D., Yuncong C. L. and Waldemar, K. (2005). Field comparison of tensiometer and granular matrix sensor automatic drip irrigation on tomato. J. Hort. Tech., 15(3): 584-591.

TECHNIQUES FOR PREPARING HEALTHY VEGETABLES SEEDLINGS

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Introduction:

A nursery is a place where seedlings, plants, trees, shrubs, and other plant material are grown and maintained until they are ready for planting in a permanent location. In order to generate high-quality seedlings, nursery management is a technical and skill-oriented activity that has to be properly attended to at different stages. Certain veggies need extra attention when they're first growing. These are the veggies that are not suitable for direct field sowing. A seedling in its early stages needs specific care, which can only be provided in a nursery.

Nursery

Objectives of the nursery

- Better quality and required quantity of plants produced.
- Generate the intended plants in a timely manner at a reasonable price.
- In a smaller nursery environment, more plants may be prepared with ease. Because there is less space, it is easier to provide the plants the right climate. Such amenities are not feasible to supply in public areas. Because there is less space, it is easier to control plant diseases and pests.
- The produce planted in nurseries is more economically lucrative since the plants mature quickly and fetch a higher price on the market.
- Given the high cost of vegetable seeds, particularly those of hybrid varieties, we can boost the germination rate of these seeds by planting them in nurseries.

The process of establishing a nursery.

Selection of a place for a nursery- Selecting a site for nursery is very important for this you should keep the following things in mind.

- The nursery area should be well fenced to protect it from pets and wild animals.
- The area should be near the water source.
- The area should be free of water stagnation.
- Nursery for transplantation should be near the main farm.
- The nursery area is best suited to receive sunlight from the south-west direction.
- Proper drainage system should be in place.

The quality of the nursery soil

Plant development depends on good soil. It should be sandy-loamy soil. Good levels of organic matter and aeration are needed in the soil. The soil's texture shouldn't be excessively fine or harsh. The ideal pH range for soil is between 6 and 7. The soil in general should be rich in all the necessary nutrients.

How to prepare nursery soil

For this deep ploughing of nursery land is required either with soil turning plough or with spade and later 2 to 3 times with cultivator. After that all the stones and weeds should be removed from the farm and the land should be leveled. Mix 2 kg well-decomposed cow dung manure and farm manure compost or leaf compost or 500 gm. vermi compost per square metre. If the soil is heavy then mix 2 to 3 kg of sand per square meter so that seed germination is not hindered.

Preparation of beds in the nursery

While making beds in the nursery the soil should be properly ploughed and kneaded to make it fine and loamy. It is good to collect and burn the remains of the previous crop and weeds etc. from the nursery area. Well rotten cow dung manure at the rate of 20 kg per square meter should be properly mixed in the soil 15-20 days before sowing. The beds in the nursery should be kept 50 cm to 75 cm in width and length as per the convenience. And it is good to keep the height of the beds 15 cm. The proper distance between two beds should be 50 cm. So that there is no hindrance in weeding and irrigation. The middle part of the beds should be raised and the sides should be slightly sloped.

There are three types of seeds:

(a) Flat nursery bed - Such beds are made in those areas where there is no rain in the spring and summer season or the soil is light sandy to sandy loamy and water does not stagnate. For the construction of these beds, the soil of the farm is made brittle by ploughing the farm two-three times. In this good rotten manure of 10 kg cow dung is mixed at the rate of per square meter.

Flat nursery bed

Advantages of a flat nursery bed:

- It offers favorable growth circumstances, such as those for germination and development.
- A high number of plants may be grown and maintained in a given area.
- Better management and care enable more efficient raising of costly hybrid seeds.
- There will be consistent water circulation, and extra water may be drained out.

Disadvantages of a flat nursery bed:

- In a flat nursery bed, overwatering can cause damping-off and seedling rotting.
- Water flows from one end of a flatbed to the other, which increases the risk of seeds being washed away.

(b) Raised nursery bed - Usually this type of seed is used for sowing seeds in the nursery. Raised beds are beneficial during rainy season. The problem of moisture dissipation is found more during rainy days in heavy soil. Therefore because of this type of beds being 10 to 15 cm high from the ground the fury of the disease is less. While making kairi, pebbles, stones, roots of plants etc. are removed from the soil, then good rotten manure of 10 kg cow dung is added per square meter. Between the lines of two beds a distance of 50 to 60 cm is kept. It is used to remove weeds for irrigation.

Raised bed nursery

Advantages of raised nursery bed:

- Raised beds will help keep some of the roaming animals and dogs out of your vegetable garden since they are elevated off the ground.
- There will be consistent water circulation, and extra water may be drained out.
- Having raised beds and adding fresh soil will assist if the soil in your yard is not suitable for planting, such as rocky, sandy, or compacted.
- Raised beds need less bending for planting, weeding, and harvesting since they are elevated above the ground.
- Seeds always have a high proportion of germination. Furthermore, tasks like weeding and taking precautions to safeguard plants are simple.
- If you have an elevated bed, you may easily increase the amount of weed protection by covering the soil with landscaping cloth.
- Raised beds enhance the overall flow of your outdoor spaces and provide architectural interest.
- There will be consistent water circulation, and extra water may be drained out.
- Raised beds enable the installation of wire mesh at the base, creating a more regulated environment. This aids in preventing intruders from using your bed.

Disadvantages of raised nursery bed:

- Additionally, raised beds typically dry out faster. You will thus need to water them more frequently. Raised beds have several drawbacks, chief among them being the additional time required for planning, construction, and upkeep.
- Building raised beds is more expensive than straight planting your vegetables in the ground. Additionally, maintaining your raised beds may cost more money.
- When making an elevated bed, it is expensive and time-consuming to purchase new soil. For example, it entails going to the store or carrying it from the location where it was delivered on-site.

(c) Sunken nursery bed - Deep beds are more useful in summer and winter season. Such beds are 10 to 15 cm deep from the ground, which protects the plants from cold air. In extreme cold and heat, bed can also be covered with polythene sheet.

Sunken nursery bed

Advantages of a sunken bed:

- Longer irrigation or rainfall deposition is made easier with a sunken bed.
- Reduces nutrient leaching.
- It enhances water absorption.
- Keeps the soil more-cool throughout the heat.
- Because the seedlings are covered, they are shielded from strong winds.
- It enhances the retention of water.
- The homogeneity of the crop was enhanced.
- It makes watering easier.
- Reduced soil evaporation is achieved with a sunken bed.
- This kind of bed aids in moisture conservation, which is beneficial when water is scarce.

Disadvantages of a sunken bed:

- Since sunken beds capitalize on infrequent rainfall, they might be troublesome in regions that are prone to floods. You may excavate and make drainage around the beds to prevent floods and prevent your plants from being washed away.
- Sunken beds are useless for farmers in colder areas because the deeper planting ditches stay colder for longer in the spring, which causes planting to be delayed. By drowning their roots, the extra moisture can also cause plants to wilt or die.

Sowing in seed beds

- Always use disease free seeds for sowing.
- Seeds should be sown in rows and rows at a distance of 5 cm.
- Seeds should be sown at a depth of 2 to 3 cm.
- There should be sufficient moisture in the beds at the time of sowing otherwise before sowing the beds should be irrigated with good quality water.

- After sowing the seeds the shallow beds should be covered with paddy straw or dry grass or polythene. So that there is no moisture.
- After germination when plants become of 2 to 3 c.m. they should be removed from the bed.
- After sowing the seeds, the lines should be leveled by covering them with topsoil or a mixture of soil and manure.
- The beds should be watered with a fountain and weeds should be removed from time to time
- The nursery should be covered with vinegar or shady net during the day to avoid excessive heat and strong sunlight.
- Shady nets are more useful than vinegar. Because that's where plants get their sunlight. And heat is conserved.
- The plant can be protected from frost by covering it with polythene at night.

Seed sowing in beds

Treatment of pre-sown seeds

Fungicides such as seresan, captan, or therum should be applied to the seeds prior to planting at a rate of two to five grams per kilogram of seed. Two grams of Bavistin per kilogram of seed should be used for a complete treatment of the seeds.

The use of shedding in the nursery

To keep the soil moist for seed germination, cover the seed bed with a thin layer of paddy straw, sugarcane waste, reeds, or any other organic wet grass in hot weather, and with plastic wet grass in cold season. It offers the following benefits: It helps improve seed germination by preserving soil warmth and moisture. It keeps weeds in check. Steer clear of rain and bright sunshine, shields the bird from harm. Protects the bird from injury.

Mulching in nursery beds

The use of water in the nursery

Nursery beds need light irrigation from a rose can until the seeds germinate. Excess rain water or irrigated water should be removed from the farm when required otherwise the plants may die due to excess of water. Watering the beds depends on the weather conditions. Open watering should be done if the temperature is high. There is no need to water during the rainy season.

Weed control in the nursery

Timely weeding in the nursery is important to get healthy seedlings. So remove them manually or sprinkle the budding herbicide like stomp in 3 ml per liter of water on the nursery bed after sowing the seeds.

Weed control in the nursery

Pest and disease management in nurseries

In general, the harm caused by illnesses and pests can be reduced by applying appropriate chemical and biological pesticides only when necessary to maintain improved nursery area hygiene.

To make plants hard and strong for transplantation

Plants should stop watering 5-8 days before transplanting in farm and vinegar or polythene or shady net etc should also be removed. This process is called pruning. The plants should be watered one day before they are removed from the beds. So that the roots are not damaged while removing the plants. Hardening helps plants cope with unfavorable environments such as low temperatures, high temperatures and hot dry air.

Precautions to be taken while transplanting seedlings

- Healthy plants of appropriate condition and height should be used for transplantation.
- The plantation work can be done in the evening in the summer season and at any time in the summer season.
- The beds should be flattened and transplanted 3 to 4 days before transplanting by preparing mulch.
- The plant should not fall in the field at the time of sowing.
- Irrigation should be done immediately after sowing. And after 3 to 4 days the dead plants should be replaced with new plants and watered.

Earnings or income in the nursery business

In the nursery business, the income is more than double the cost. This business depends on your hard work and demand. Some plants grow from seeds, while others require grafting. You don't need much money for this. Because even the smallest plant costs about 40-50 rupees. If the cost of a plant is added, it will hardly cost Rs 10 to 15. In this way, the margin in this business is more than double. If you sell even plants in a day, your income can be up to Rs 3500 per day. Even after reducing the cost, 2000 to 2500 rupees will come in your hand. In this way, you can earn up to seventy five thousand rupees per month.

References:

1. B. Nair, K.P. Singh, P. Chand. (2014). Fundamentals of vegetable crop production. Scientific Publishers.

2. Bharathi PVL, Ravishankar M. (2018). Vegetable nursery and tomato seedling management guide for south and central India. World. Veg. Publication No. 18-829. World Vegetable Center, Taiwan. 30 p.

3. Singh, B., Yadav, H. and Bharat, M. K. (2019). Preparing healthy seedling of vegetable crops through high technique. Short courses training manual- Advances technique of vegetable production in greenhouse. CSAUAT, Kanpur. U.P.

4. Tomar, B.S. (2019). Technology for preparing healthy seedling of vegetables in open field. Short courses training manual- Advances technique of vegetable production in greenhouse. CSAUAT, Kanpur. U.P.

VALUE ADDITION, PROCESSING AND BRANDING IN ORGANIC VEGETABLES

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Abstract:

India stands second to the leading producer of Vegetables in the world – China, with an estimated, staggering production of 204.84 million metric tonnes. Despite massive production, there are not many players in vegetable processing at regional and National level. The development of vegetable product is vital as it improves shelf life of the vegetables and it also improves the quality of vegetable by the addition of value in it. These crops have high potential in maintaining sustainability in terms of economy country. Most vegetables are under-estimated despite having potential processing capacity and high nutritive value. Value addition, Processing and Branding in Vegetables are emerging strategies in achieving these goals. In terms of production challenges in agriculture, sustainability is not only a catchword but a necessity to feed the growing global population, farmers dilemma to enhance profitability while also minimizing environmental impacts. These can potentially generate ecologically conscious enterprises that flourish on the pretext of reducing food wastage and losses and increasing profitability. There is a wide array of traditional foods, that can be re-visited in order to innovate and make them commercially viable which can potentially diversify the platter and also sustain rural economies.

Introduction:

In the contemporary times, agriculture has transformed on many fronts. It has shifted from mere production-sustenance to profitability of the cultivator. While India enjoys the privilege of being second leading producer of vegetables, after China, in the world. Vegetables are good source for dietary nutrients such as vitamins, fibres and minerals with a moisture content of more than 80%. (Orsat *et al.*, 2006). Per capita consumption of vegetable in India is lower than daily requirement. It happens due to high post-harvest losses (20-40%) of fruits and vegetables in India. (Nagi *et al.*, 2020) A major global challenge is ensuring food security to the ever-growing population whilst also being environmentally sensible. According to FAO, 70% increase in food production is needed to make the food available to the world population which will reach 9 billion by 2050. Postharvest losses are approximately 20-50% in developing countries and 10-15% in developed countries.

India's climatic and soil condition provide an excellent platform for the cultivation of a wider variety of vegetables. India is producing around 85 million tons of fruits and 170 million tons of vegetables every year. The present situation demands considering Agriculture as the major economic and commercial activity to enhance growth and national economy. The huge production base of fruits and vegetables provides excellent export opportunities for India.

Despite this advantage, India's share in the global market is insignificant and accounts for only 1.7 per cent of the global trade in vegetables and 0.5 per cent in fruits (Thulasiram, 2020). India loses about 35-45% of the harvested fruits and vegetables during handling, storage, transportation etc. leading to the loss of Rs. 40,000 crores per year. Estimated loss of Vegetables such as Onion 25-40%, Garlic 08- 22%, Potato 30-40%, Tomato 5-47%, Cabbage & cauliflower7.08-25.0%, Chili 4-35%, Radish 3-5% and Carrot 5-9%. The losses of vegetables are a serious matter of concern for India's agricultural sector. The highly perishable commodities of vegetables are lost after harvest due to insufficient methods of harvest, decay, and over-ripening, mechanical injury, weight loss, trimming and sprouting. So that, these aspects are to be looked critically to see if any improvement in the present state of vegetable industry, especially in the context of processing and marketing are to be accomplished. (Bala *et al.*, 2020) In India maximum vegetables are processed to prevent it from post-harvest losses. Since 2011 the global vegetable processing industry has grown and is significantly expected to grow in India due to industrialisation and increased standards of living.

Vegetables play a major role in the human diet as they are rich source of nutrients. They contain many phytochemicals which prevent many diseases such as hypertension, cancer, heart diseases etc. Hence consumption of vegetables is most important to lead a healthy life and achieve nutritional security.

Currently, the Indian food processing industry is in a nascent stage - but is poised for high growth in years to come. The industry registered a compound annual growth rate (CAGR) of 15.6 per cent during FY07-FY12 (MOFPI, 2012). In India, the industry is largely dominated by the ready-to-eat segment, which contributed nearly 90% of the total sales of packaged foods in India FY12 (MOFPI, 2012). Development of fruit and vegetable processing is critically important to the expansion and diversification of the agricultural sector in India as well as Bengal. Such activities would reduce seasonality of consumption of a range of processed food; minimize post-harvest losses, and increase profitability and sustainability of production systems besides their impact on increasing farm income, rural employment and foreign exchange earnings and reduction in marketing risks. (Roy and Ojha, 2012)

Food processing is one of the largest global sectors at $7 trillion annual production. According to NSDC's report on food processing the Global Processed Food Industry is valued at US $ 3.2 trillion and accounts for over 3/4th of global food sales. Despite the large size of the industry, only 6% of the processed food is traded the world over as compared to bulk agricultural commodities where 16% of produce is traded. The USA is the single largest consumer of processed food and accounts for 31% of the global sales. This is because as countries develop, high quality and value-added processed food is preferred over staple food. Indian food processing industry ranked fifth in terms of production, consumption, export and expected growth (Singh, 2012; Hussain & Yadav, 2016).

Food processing industry including fruit and vegetable processing is the second largest generator of wastes into the environment only after the household sewage. Several value-added products such as essential oils, starch, pectin, dietary fibers, acids, wine, ethanol, vinegar, microbial pigments, flavors and gums, enzymes, single cell proteins, amino acids, vitamins, organic compounds, colors and animal feed can be made out of the waste from processing industries (Joshi *et al.*, 2020). A well developed food processing industry is expected to increase farm gate prices, reduce wastages, ensure value addition, promote crop diversification, generate employment opportunities as well as export earnings. Growth of food processing industries would provide expanding demand for farm produce, vegetables, fruits and other greens that would help improve agricultural incomes.

The food processing industry has strong backward linkages with rural economy, as all the raw material is produced by rural people. Hence, any growth in food processing industry, positive or negative will have a direct impact on economy of rural India. Food processing industry would help in reducing rural urban disparity and ensuring household food and nutritional security for all at an affordable cost. The development of agro-based industries are easy to established and have the potential of providing steady and additional income to the rural people without making large initial investment. Thus, development of agro-based industries plays a significant role in the process of economic development of the country. Promoting food processing is perceived as a promising way to enhance farm incomes in India as it raises the demand for agricultural products for further value addition (Ghosh, 2014).

Value addition in vegetables

Value addition is a strategic approach in post-harvest management that involves enhancing the quality, market value, and economic potential of agricultural products, such as fruits and vegetables. Value addition to food has assumed critical importance in the last decade due to socio-economic and industrial factors. Preservation and processing of food products has a prolonged history in human civilization. Organized food cultivation is believed to have taken place 10,000 to 15,000 years ago. By the middle of the nineteenth century, common agro processing industries included hand pounding units for rice, water power driven flour mills, bullock driven oil ghanies, bullock operated sugar cane crushers, paper making units, spinning wheels and handloom units for weaving. Large scale commercial food processing and retailing originated in Western Europe and the United States and the two regions today account for 35 per cent of the world's largest food manufacturing firms.

As vegetables are seasonal they are not available throughout the year. Fruits and Vegetables are highly valued in human diet mainly for their minerals and vitamins content (Grubben et Journal of Current Research in Food Science www.foodresearchjournal.com ~ 42 ~ al., 2014). They are good sources of vitamin C, folate, βcarotene (pro-vitamin A), potassium, iron, zinc and calcium (van Jaarsveld *et al.,* 2014). Also, they are substantially high in antioxidants, bio-active compounds and fibers (Khandpur & Gogate, 2015; Wadhwa, Bakshi, & Makkar, 2015) Value addition is the process of converting vegetables to a more valuable from than its original form. Vegetables help in maintaining strong metabolism. Hence value addition is useful in achieving the food security (Saisupriya and Saidaiah 2021)

Status of vegetable processing in India

Vegetables offer a variety of benefits when consumed but they are not always well marketed, packaged or readily available to consumers, especially those living in urban areas. The vegetables have largely been ignored over the years, yet they are said to be highly nutritious crops that have potential to boost income of both women farmers and traders who usually produce and sell them. Poor infrastructure for transporting and handling indigenous vegetables is now a greater constraint than market demand or price in urban areas (Biodiversity for Food and Nutrition Project, 2012).

It is observed that the current status in availability of vegetables only meet half of the requirement of vitamins and minerals. Processing of vegetables by developing such techniques, which is easy to operate as well as can also produce economic quality product. In India less than 2% of the vegetables from total production is processed and in Brazil the 70% and in Malaysia around 83%. One of the most common methods for preservation of Vegetables is dehydration. Dehydrated forms of vegetables are consumed in several forms, without affecting its nutrient value. Due to post harvest losses of vegetables due to poor management, the losses of farm produce are very high. In studies it was recorded that 75.000-1, 00, 000 crore per year losses are cause due to post harvest management of food commodities (Nagi *et al.,* 2020). Demand for processed value added vegetables is growing and can be achieved through low cost processing techniques with the maintenance of nutritive and sensory quality. On average of 40% in developing countries and 70% in developed countries while in India only 2-2.5% processing is done. India is the second-largest producer of vegetables in the world next only to China and accounts for about 12 percent of the world production of vegetables. This is comparatively low when compared to other countries like Brazil (30 percent), USA (70 percent) and Malaysia (82 percent). India ranks 1st in the world in terms of production ginger, okra and second-largest producer of potatoes, green peas, tomatoes, cabbage and cauliflower. During 2021-2022, the production of horticulture crops was about 342.33 million tons from an area of 28.08 million hectares. As per National Horticulture Database published by National Horticulture Board, the total area under production of vegetable in India is nearly 11.2Mha with the production of 204.61 million tons during 2021-2022 (NHB, 2022 2nd estimate).

In its bid to give impetus to the food processing industry in the country, the Government of India has established an altogether separate Ministry of Food Processing Industries for the development and promotion of food processing industries. To boost vegetable processing, the Ministry is extending financial support for setting up new units, modernization and up-gradation of existing units. Besides, the Agricultural and Processed Food Products Export Development Authority (APEDA) has been playing a major role in the export effort of processed vegetables by providing various services to the trade and industry such as identifying new markets, regular participation both in national and international trade fairs and also launch of promotional campaigns.

Commodity	**2019-2020**		**2020-2021**		**2021-22**	
	Quantity	**Rupees (in Lakhs)**	**Quantity**	**Rupees (in Lakhs)**	**Quantity**	**Rupees (in Lakhs)**
Processed Vegetables	2532769.74	276053.17	4033553.79	371862.96	4606210.2	398645.2

Source: DGCIS (Annual export)

The idea that Government has allocated a separate Ministry for Food Processing is an indication of its commitment to achieve growth of agro-processing industry in the country. Presently, processing is witnessed in the sectors of Dairy, Fruit and Vegetable Beverages, Dehydrated Products, Grains and Cereals, Beer and Malt extracts, Grain based alcohol, Fisheries, Poultry and Frozen Meat and Consumer Foods.

Sector	**Products**
Dairy	Whole milk Powder, Skimmed Milk Powder, Condensed Milk Powder, Ice-cream, Butter, Ghee, Cheese
Fruits & Vegetables	Beverages, Juices, Concentrates, Pulp slices, Concentrated Products, Potato Wafers, Chips, etc.
Grains and Cereals	Flour, Bakeries, Starch, Glucose, Corn Flakes, Malt and Beer Extracts, Grain based alcohol
Meat and Poultry	Frozen and Packed– mostly in packed form, egg powder
Consumer Foods	Snack foods, namkeen, ready-to-eat foods, alcoholic and non-alcoholic beverage

Source: Ministry of Food Processing India, Annual report, 2017

Processing of vegetables

There is compelling evidence that there are huge post-harvest losses in major vegetable crops in India. The average losses in crops of Onion are 8.20% Tomato 12.44% Cabbage%, Cauliflower 9.56% Green pea 7.45%, Potato 7.32%, Tapioca 4.58% (Jha *et al.*, 2015). In case of perishable foods like vegetables, scientific processing of vegetables is a technique to reduce spoilage and prevent food borne diseases while maintaining the nutritional value, texture and organoleptic quality through optimal treating of these. Different types of value-added products of vegetables include dehydrated vegetables, beverages, jams, purees, sauces, pickles, chutneys, juices, flour, canned vegetables, minimally processed products and vegetable powders. (Saisupriya and Saidaiah 2021). In common parlance, food processing is any method that can convert fresh food into a food product. This involves not one, but a series of procedures like washing, trimming, pasteurisation, freezing, fermenting, cooking, packing etc. The ultimate idea is to prolong shelf-life and reduce culinary procedures.

The new age world has a revived consciousness of human health. With both men and women working, the cooking and consumption patterns of food are undergoing a massive transition. With more time at the workstation, little time and energy are left to cook elaborate meals on the kitchen counter thus leading them to seek convenient options like ready-to-cook or ready-to-eat vegetables or semi-cooked meals. The Ready-to-Eat Meals segment covers prepared food and meals that can be eaten as is or after minimal preparation. These meals do not require cooking and are typically consumed after heating. s (Rais and Sheoran, 2015). These meals may also include disposable eating utensils. Classic frozen foods include meat, fish, vegetables, filled pasta, and frozen pizzas. (Statista.com, 2024) The market is expected to grow annually by 9.23% (CAGR 2024-2028). In the Ready-to-Eat Meals market, volume is expected to amount to

21.89bn kg by 2028. The Ready-to-Eat Meals market is expected to show a volume growth of 6.9% in 2025. (Statista.com) Consumers now prefer to purchase vegetables, fruit and other agri-products from super place super markets and modern retail stores than conventional wet markets. (De Corato, 2019).

Packaging and branding in organic vegetables

Packaging and labelling of fresh fruits and vegetables is one of the most important stages in the long and complex journey from producer to consumer. The packaging is very important for the company and the company brand to build their brand awareness. A good packaging can guide the company to achieve success goals. If a company wants to attract customer's attention towards their packaging, these six elements (colour, materials, shape, and size, graphic and convenient) should be focused and surveyed by the company. A good packaging can also help the company to build the brand position in the competitive market. Branding is the process of creating a distinct identity for a business in the minds of the target audience and the general population. The aim is to build relationships with your audience, which can eventually turn them into loyal customers. Vegetables can be sold in fresh with bare-minimal processing or in processed food form. Bare Minimal processing is defined as the handling preparation, packaging, and distribution of agricultural commodities in a fresh like state, and may include processes such as peeling, dicing, slicing, trimming and curing for easy consumption of customers (Corato, 2019 and Bhat, 2013).

Net Bags

Leno Bags

HDPE Bags

Punnet Packaging

Cling Film Wrap

Perforated Plain Packaging

Rubber Plastic Mesh

Bags, crates, cartons, basket, hampers, bulk boxes and pallet containers are convenient containers for handling, transporting and marketing fresh produce. Plastics have placed an important role as an efficient packaging material. Apart from cost effectiveness they protect the fruits from microbial infection, moisture, weight loss and a control ethylene concentration in the package. For smart materials to be adopted in packaging, they need to be inexpensive relative to the value of the product, consistent, precise, reproducible in their range of operation and environmentally benign and food contact safe.

Challenges in vegetables processing in India

Evidently, post-harvest losses can be minimal if vegetables are stored under controlled humidity and temperature. In our country, storage facilities with controlled conditions are available in select cities and at high costs marginalising a small vegetable grower who cannot afford the service. Also, losses in leafy vegetables and fruit vegetables are much more than in root and tuber vegetable crops. Therefore, it could be advantageous if cold storages facilities are constructed by government agencies or by private sectors near production areas for storing the produce, which can be further used by processing industries. During a peak season, there is a local glut of produce, due to these postharvest losses in terms of quality and quantity occurs due to

- Lack of Adequate transportation facilities
- Absence of optimal storage facilities
- Poor availability of packaging material and rates

Conclusion:

Presently, India is at the tip of the ice-berg of the food processing industry. Its given share in the global food factory stands at a dismal 1.5%. Our processing for agriculture products are quite low as compared to other nations despite having substantial raw material. The government lays emphasis on encouraging farmers to become agri-prenuer by increasing the percentage of vegetables processed to over 10% by 2025. While we are witnessing a new wave of innovative products like nut butters, herbal and floral teas, millet-based breakfast mixes etc. there is a need to increase the infrastructural support for this industry to flourish and sustain. Vegetable processing is a lucrative industry in India because of the crops' nutritional value. When compared to fresh veggies, processed products with value added have a huge market demand and higher market value, which can increase a farmer's revenue by doubling it.

References:

1. De Corato, U. (2019). The market of the minimally processed fresh produce needs of safer strategies for improving shelf- life and quality: A critical overview of the traditional technologies. J. Agric. Res., 4 (1): 2.

2. Bhat, Shanky (2013). Minimal processing and preservation of fruits and vegetables by active packaging. Internat. J. Herbal Medicine, 1 (2) : 131.
3. Bala Gautam S, KK, Sahu M. A review of Post Harvest Management and value addition of horticultural crops. International Journal of Creative Research Thoughts (JCRT). 2020 July;8(7). ISSN: 2320-2882. www.ijcrt.org 8. Bokelmann
4. Grubben G, Klaver W, Nono-Womdim R, Everaarts A, Fondio L, Nugteren JA, Corrado M. Vegetables to combat the hidden hunger in Africa. Chronica Horticulturae. 2014;54(1):24-32.
5. Ghosh A, Thomas TA, Cudak MC, Ratasuk R, Moorut P, Vook FW, Rappaport TS, MacCartney GR, Sun S, Nie S. Millimeter-wave enhanced local area systems: A high-data-rate approach for future wireless networks. IEEE Journal on Selected Areas in Communications. 2014 Jun 3;32(6):1152-63
6. Hussain A, Yadav MK, Bose S, Wang JH, Lim D, Song YK, Ko SG, Kim H. Daesiho-Tang is an effective herbal formulation in attenuation of obesity in mice through alteration of gene expression and modulation of intestinal microbiota. PLoS One. 2016 Nov 3;11(11):e0165483.
7. Joshi VK. Value addition to Fruit and Vegetable Processing Waste- An Appraisal. Int. J Food Ferment. Technol. 2020;10(2):35-58.
8. Khandpur P, Gogate PR. Effect of novel ultrasound-based processing on the nutrition quality of different fruit and vegetable juices. Ultrasonics Sonochemistry. 2015 Nov 1;27:125-36.
9. Manju Wadhwa MW, Bakshi MP, Makkar HP. Waste to worth: fruit wastes and by-products as animal feed. CABI Reviews; c2015 Oct 14. p. 1-26
10. Rais, M. and Sheoran, A. (2015). Scope of supply chain management in fruits and vegetables in India. J. Food Process. & Technol., 6 (3) : 2.
11. Roy K, Mitra I, Ojha PK, Kar S, Das RN, Kabir H. Introduction of rm2 (rank) metric incorporating rankorder predictions as an additional tool for validation of QSAR/QSPR models. Chemometrics and Intelligent Laboratory Systems. 2012 Aug 15;118:200-10. 33. Grubben G, Klaver W, Nono-Womdim R, Everaarts A
12. Saisupriya P, Saidaiah P. Value Addition of Vegetables. Vigyan Varta. 2021;2(12):19-22. www.vigyanvarta.co
13. Thulasiram R. Status and Constraints in Indian Fruits and Vegetable Export. 2020;1(4). www.aiasa.org.in 27. Vasantha HP, Yu Li J. Value-Added Fruit Processing
14. Van Jaarsveld P, Faber M, Van Heerden I, Wenhold F, van Rensburg WJ, Van Averbeke W. Nutrient content of eight African leafy vegetables and their potential contribution to dietary reference intakes. Journal of food composition and analysis. 2014 Feb 1;33(1):77-84. 35.

HARNESSING ARTIFICIAL INTELLIGENCE FOR AGRICULTURAL ADVANCEMENTS: A DATA DRIVEN INSIGHT

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Introduction:

According to the United Nations FAO (Food and Agriculture Organization), the global population is projected to increase by an additional 2 billion by 2050. Agriculture plays a crucial role in ensuring the sustainability of economies, driving long-term economic growth and structural transformation. To meet the demands of this expanding population, a 70% increase in agricultural production is needed. However, with only about 10% of this increase achievable through unused lands, the remaining 90% must be derived from intensifying current production methods. Yet, this intensified production poses challenges, including the potential deterioration of soil health and quality due to nutrient depletion and heightened pest and disease pressure. This could result in reduced soil fertility and productivity. Therefore, there is a pressing need to adopt more efficient farming practices, leveraging recent technologies (AI) and solutions, to address current agricultural challenges.

Over the past decade, the transformative influence of artificial intelligence (AI) in agriculture has revolutionized traditional farming practices and enhanced efficiency across various aspects of the agricultural sector, leveraging its capacity to mimic cognitive functions such as learning and problem-solving.

Artificial intelligence: The science and engineering of making intelligent machines that thinks and works like human. It is analytics and decision making from the data collected by internet of thing **(**John McCarthy, 1956).

Internet of Things (IOT): IOT is a technology which tends to connects all the objects in the world to the **Internet** and gathers the data and store it in the cloud. This uses sensors, cameras and other devices to show every factor and action involved in farming into data. Cloud provides services over network *i.e.*, on public networks or on private networks, *i.e.*, WAN, LAN or VPN.

Cloud Computing involves manipulating, configuring, and accessing applications via the internet. It offers online data storage, infrastructure and application and it is both combination of software and hardware based computing resources delivered as a network service.

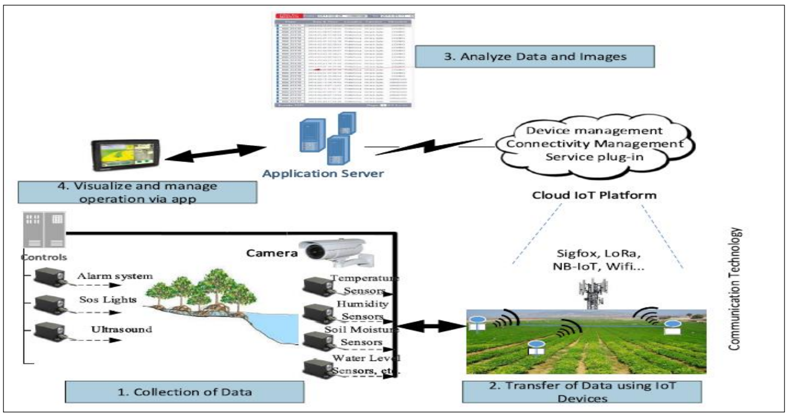


Figure 1: IOT and AI ecosystem

Components of artificial intelligence:

1) **Machine learning:** Machine learning algorithms enable computers to learn from data and improve their performance over time without explicit programming. This involves techniques such as supervised learning, unsupervised learning, and reinforcement learning.
2) **Artificial Neural Networks (ANN):** Neural networks are computational models inspired by the structure and function of the human brain. They consist of interconnected nodes organized in layers and are used for tasks like pattern recognition, image classification, and natural language processing.

   Highly interconnected network of many simple processing units called *neurons*, which are analogous to the biological neurons in the human brain.
3) **Natural Language Processing (NLP):** NLP involves the ability of computers to understand, interpret, and generate human language. This includes tasks such as speech recognition, sentiment analysis, machine translation, and text summarization.
4) **Computer vision:** Computer vision enables machines to interpret and analyze visual information from images or videos. This involves tasks such as object detection, image classification, facial recognition, and scene understanding.
5) **Expert systems:** Expert systems are AI systems that emulate the decision-making abilities of human experts in specific domains. They use rules and logic to interpret information and provide recommendations or solutions to complex problems. Simulate reasoning by applying knowledge and interfaces.
6) **Robotics:** Robotics involves the integration of AI and physical systems to create autonomous machines capable of sensing, perceiving, and interacting with their environment. This includes tasks such as autonomous navigation, object manipulation, and collaborative robotics.
7) **Knowledge representation:** Knowledge representation involves organizing and structuring knowledge in a format that can be used by AI systems to reason, infer, and make decisions. This includes techniques such as ontologies, semantic networks, and knowledge graphs.

8) **Planning and optimization:** AI systems use planning and optimization techniques to generate sequences of actions or decisions that achieve desired outcomes while considering constraints and objectives. This includes tasks such as route planning, resource allocation, and scheduling.

Applications of AI for agricultural advancement:

a. Soil and water quality analysis:

To test the quality of soil and water, farmers typically have to send samples out to labs. The process can be time-consuming - results may be outdated by the time they receive it and for small farmers, it is a costly process.

I. AgroPad: IBM researchers in Brazil have developed an AI-powered prototype to help farmers to easily conduct their own chemical analyses - on location, in real-time. This prototype "could revolutionize digital agriculture and environmental testing.

The AgroPad is a paper device about the size of a business card. It has a microfluidics chip inside that can perform a chemical analysis of a water or soil sample in less than 10 seconds. Farmer simply have to put sample on one side of the card, and on the other side, a set of circles provides colorimetric test results. The current prototype measures pH, nitrogen dioxide, aluminum, magnesium and chlorine in soil and water.

Figure 2: AgroPad usage and processing

Using a dedicated smartphone app, the farmer can receive immediate, precise results. The app uses machine vision to translate the color composition and intensity into chemical concentrations, with results more reliable than those that rely on human vision.

b. Nutrient deficiency detection in plants:

All this time, deficiency surveillance is conducted using manual observation. The growers inspect condition of plants regularly whether nutrients of plant are fulfilled well. This was time consuming and less accurate as the human vision can leads to errors if he is not an expert. The automatic detection and classification of plant disorders has received considerable attention in the last two decades (Barbedo, 2013).

- Some technologies required for automatic detection are
  - Reflectance spectroscopy

- Fourier-transform infrared microspectroscopy
- Chlorophyll fluorescence spectroscopy
- Digital Image

i) Non imaging and imaging chlorophyll fluorescence

It works on the fluorescence emission pattern of leaves, tissues and even whole plant. The fluorescence emission is captured when part of light energy adsorbed by plant chlorophyll for photosynthesis is re-emitted when excited with blue-green light.

The ratio used for chlorophyll indicator is F690-F735 (blue-red) while detection of nutrient stress relies on F440-F690 and F440- F740.

ii) Multispectral and Hyperspectral imaging:

Multispectral systems measure reflectance in broad bands of red, green, blue and near-infrared regions and can be extended to a maximum of ten wavelengths.

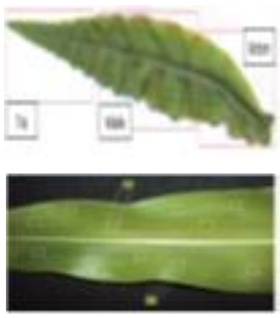
iii) Development of vegetative indices based on multispectral wavelengths:

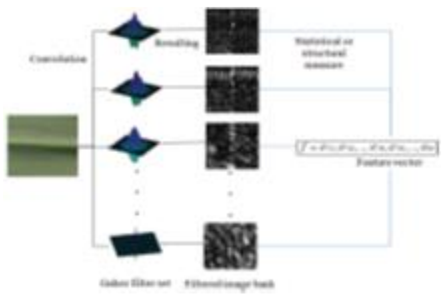
Vegetation Indices were developed based on several selected bands within the visible (blue, green and red bands) and near-infrared spectral regions in multispectral imagery.

The Normalized Difference Vegetative Index commonly used index in multispectral application in detecting plant physiological variability.

Artificial intelligence based nutrient detection are constituted in the steps:

- Acquisition
- Image segmentation
- Feature extraction
- Classification/identification





The main approach used for automatic detection of the nutrition deficiencies

1) **Regression analysis:** The goal is to predict a nutrient quantity with certain input variables. In the case of nutrition deficiency detection and classification, the idea is to either directly predict the content of the nutrient of interest or to indirectly detect deficiencies by predicting the content of related variables (e.g. chlorophyll concentration in the case of nitrogen).
   - Linear regression is most common technique used for the detection of nutrition deficiencies. The green colour channel is often used as input to calculate a variety of color and vegetation indices. Saberioon et al. (2013) applied Kawashima index (R-B/R+B) to determine nitrogen status of a specific rice cultivar submitted to four different treatments. The coefficient of determination (R2) between the calculated indices and the reference SPAD values was 0.56.

- Yuzhu et al. (2011) used the normalized green index G/(R+G+B) to determine nitrogen status in pepper plants at flowering and fruiting stages submitted to six treatments. The coefficient of determination between the calculated index and the actual nitrogen concentration was 0.62.
- Prey *et al.* (2018) used the HSV (hue, saturation, value) colour space to derive the proportion of green pixels in the images (canopy cover). This work focused more on the use of multispectral and hyperspectral spectrometry for deriving nitrogen status and dry weight in wheat.
- The coefficient of determination between canopy cover and nitrogen content was low (0.19). Borhan *et al.* (2017) adopted the average and variance of the G and R bands to predict SPAD readings in potato plants.
- The coefficient of determination between the features and SPAD readings varied from 0.79 to 0.87.

2) Machine learning classification techniques:

Machine learning classification techniques aim at labeling data/ Image according to certain criteria. All the supervised learning use a set of labeled data to train the classifier to tackle the certain problem.

The variety of machine learning techniques applied are:

- Artificial neural networks (ANN)
- Support vector machines (SVM)
- Discriminant analysis techniques (DA)
- k-nearest neighbors (kNN)
- Fuzzy logic
- Statistical classifiers
- Genetic algorithms (GA) and
- Random forests (RF).

1. Artificial Neural Networks (ANN):

Artificial neural networks come in a wide variety of architectures and topologies. The most common type is the Multilayer Perception (MLP), which is a class of feed forward neural network that uses the back propagation technique for training. The average classification accuracy was 0.67.

Culman *et al.* (2017) created PalmHAND, an innovative smart phone app for farmers to detect Mg, K, or N deficiencies in oil-palm plants using leaf photos. It can function offline but utilizes Microsoft's Azure Cloud as an IoT device for data storage and visualization when online. PalmHAND aids in fertilizer management in remote oil-palm plantations, offering on-device diagnosis, site-specific nutrient management, and mobile/web apps for data gathering and analysis under the Internet of Things framework.

2. Deep learning technique:

Condori *et al.* (2017) gave procedure for digital image extraction for nutrient deficiency detection in maize.

Step 1: The input image is divided into non-overlapping square regions and then some regions are extracted randomly.

Step 2: Some of those regions are discarded using global mean vs local mean criteria. **Step 3**: Feature vectors are created by processing the remaining regions with traditional texture methods or deep learning methods.

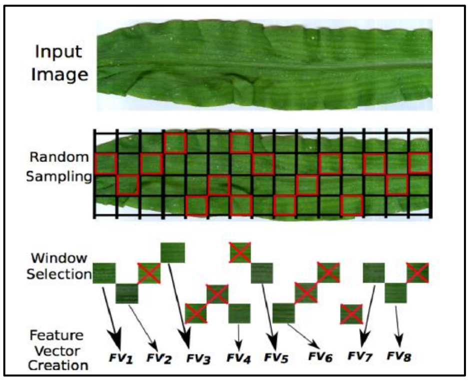


Figure 3: General image analysis procedure

3. Support vector machine (SVM):

Asraf *et al*. (2012) enumerated the potential of computer vision in recognition of nutrition disease namely nitrogen, potassium and magnesium of oil palm trees with SVM as classifiers. SVM with Polynomial kernel with soft margin produces the best performance in average of 95 per cent correct classification.

II. SoilMATTic:

SoilMATTic was developed to revolutionize soil analysis, providing faster and more accurate results compared to traditional methods. This Arduino-based prototype automates the entire process of testing soil macronutrients and pH levels, along with providing fertilizer recommendations. It utilizes stepper motors and pumps to automate chemical reactions during testing and includes an onboard printer for instant fertilizer recommendations. Using digital image processing, SoilMATTic efficiently identifies nitrogen, phosphorus, potassium, and pH levels. The system consists of five stages: automated soil testing, image acquisition, image processing, training system, and recommendation. Artificial Neural Network technology ensures rapid and precise image processing. With a database storing and managing 356 images, the system achieves 96.67% accuracy in identifying soil properties and provides tailored fertilizer recommendations for various crops through printed reports (Richard *et al.*, 2018).

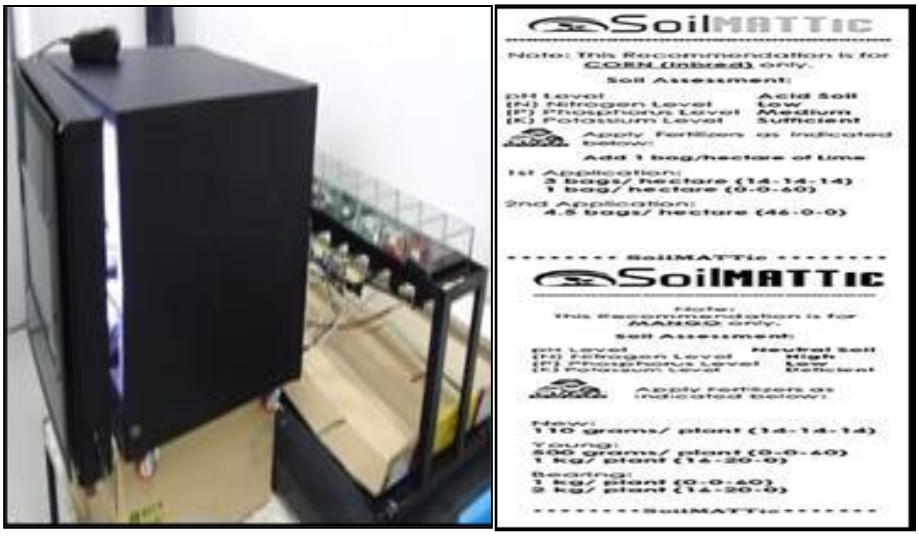
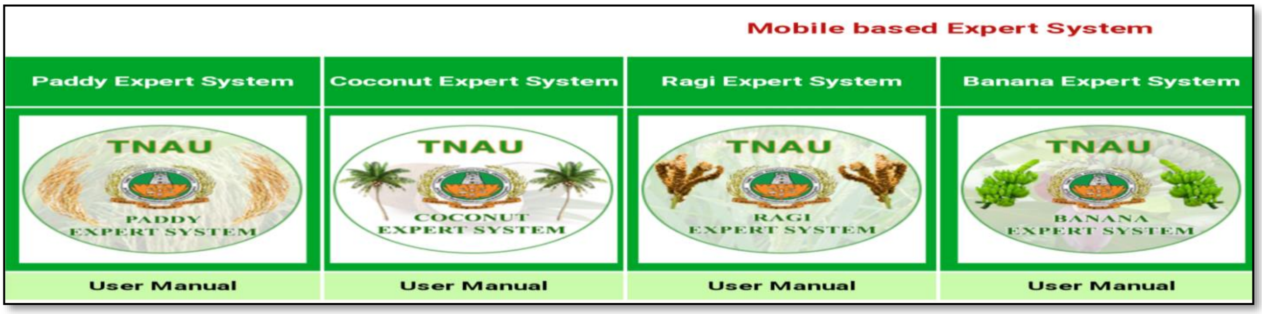


Figure 4: Automated Soil Testing Box with Chemical Compartment

III. Crop Doctor: (TNAU- Expert System)

Crop doctor is a vital component in the expert system, which act as artificial intelligence. It is picture and image based 'if and then rule' based programme which has written using dot net programme. It deals with diagnosing the pest, disease and nutritional disorders affecting the selected crops. The first obvious sign is given as thumbnail images in the Key Visual Symptoms (Primary Symptom) with multiple stages (Secondary Symptoms). Primary and secondary symptoms have been documented in stage-by-stage and loaded in the expert system shell by using if and then rule based programme.



IV. AI in insect pest management:

Insect pests pose significant challenges to agricultural productivity, causing substantial crop losses and economic damage globally. Use of indiscriminate pesticide use, have led to environmental contamination and health risks. To address these issues, advanced technical solutions are needed, including smart agriculture techniques that leverage AI for precision control of plant insect pests. Drones, which operate based on AI principles, are being utilized for spraying pesticides over larger areas with precision, ensuring complete coverage of crops while minimizing environmental impact. Computer vision technology, another application of AI, plays a crucial role in spotting agricultural disorders and preventing them. UAVs equipped with computer vision AI can automate pesticide spraying uniformly across fields, with real-time recognition of target areas. This approach reduces the risk of contaminating crops, humans, animals, and water resources, thus improving insect pest management efficiency.

The utilization of AI and related technologies in insect pest management can significantly contribute to achieving the following tasks:

- **Image recognition and deep learning:**

Image recognition technology based on deep learning is used to automate the detection and classification of insect pests. Techniques such as YOLO (You Only Look Once) object detection and Support Vector Machines (SVM) are employed for accurate pest identification and counting, achieving high levels of accuracy. Advanced techniques such as Faster R-CNN and cloud computing systems enable the detection and classification of crop pests. The developed image-based recognition system successfully identifies five classes of common crop pests.

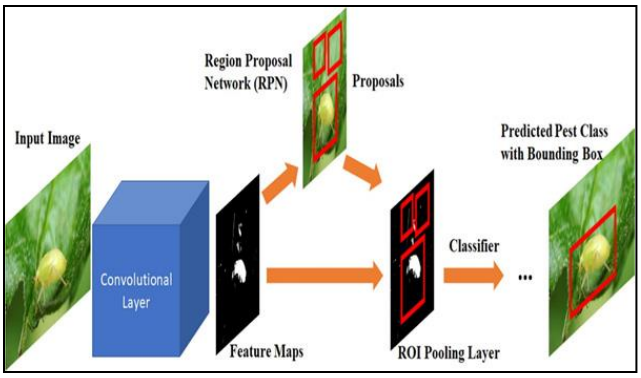


Figure 5: Depicting basic workflow of Faster R-CNN for detection and classification of target crop pests

- **Mobile apps for pest identification and advisory:**

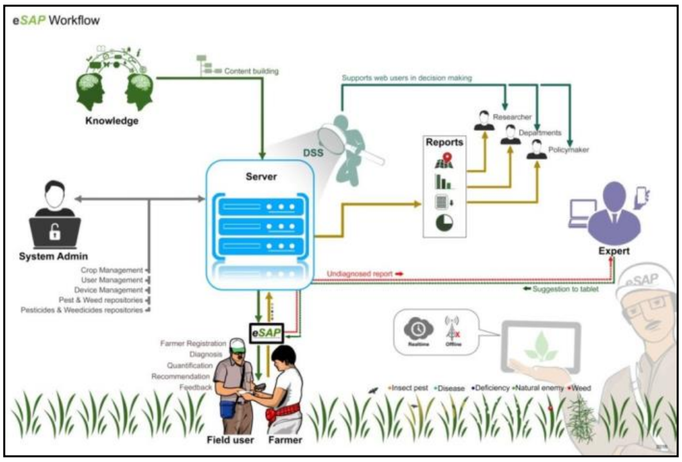
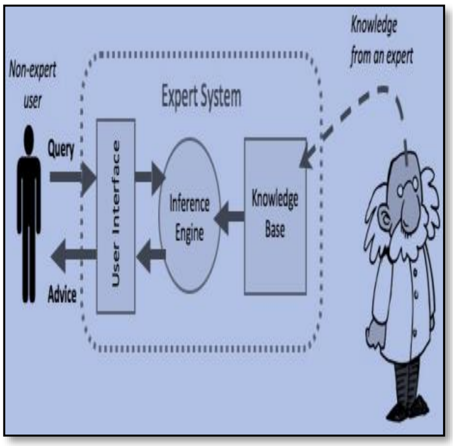


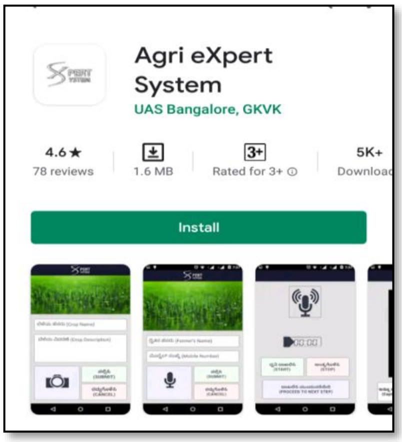
Figure 6: e-SAP work flow

Numerous mobile apps based on AI have been created by various research institutes and scientists to efficiently identify and manage insect pests in different crops. e-SAP (Electronic Solutions against Agricultural Pests) have been developed for identifying and advising various crop pests, diagnosing pest damages. Other technologies detect plant diseases and nutrient deficiencies affecting various crops. These apps utilize trained deep learning algorithms to analyze images captured by users and provide actionable recommendations for pest management.

- **Agricultural Pest Prediction and Advisory (APPA) (Developed by UAS, Bengaluru):**

Among ICTs there has been increasing use of mobile phones with number of services provided by various agencies. Mobile phones have penetrated rural India bringing by the digital education. In this background, an android based mobile app has been developed for disseminating the technologies. This mobile application is in continuation with the web portal (www.ngtforewarningpd.com) NGT forecasting pests and diseases. Here farmers can view the forecast and advisory whenever it needs. It is enabled to gather the open-source weather data of current location by GPS (mobile GPS should be on). Model incorporated will predict the pest severity based on the local weather condition. Advisory will be issue based on the pest severity. This mobile application increases the accuracy and is user friendly.





- **NGT expert system**

National Green Tribunal **(**NGT) expert system is an android mobile app for managing pests and diseases on field by experts which would be reported by individual farmers or pest monitors on behalf of farmer. Farmers report the problem on field by using android app which is transferred to designated expert. Experts then provides advisory to the farmer through text SMS or voice SMS.

- **Utilization of drones for pesticide spraying:**

Drones equipped with AI technology are employed for aerial spraying of pesticides in crops such as rice, wheat, corn, cotton, pepper, and sugarcane. Optimization of drone operational parameters, including flight speed, flight height, nozzle type, and payload, ensures efficient pesticide application and improved insecticidal use efficiency.

- **Effectiveness of drone technology in pest management:**

Aerial sprays using drones are found to be effective in controlling various pests such as brown plant hoppers in rice, aphids and spiders in cotton, and fall armyworm in sugarcane. Drone technology, operating on principles of artificial intelligence, offers advantages over conventional spraying methods, resulting in more effective insecticidal spray and enhanced pest management in agricultural and horticultural crops.

V. The FARM CALCULATOR

The FARM CALCULATOR App is a versatile tool for instant calculations related to farming activities. It offers several useful features:

Fertilizers (NPK) Calculator: Determine the precise quantity of NPK fertilizers needed per unit area, either based on recommendations or soil testing, to optimize costs and prevent soil degradation.

Pesticides/fungicides/herbicides calculator: Accurately apply the right amount of pesticides, fungicides, or herbicides from various brands with different active ingredients to effectively manage pests, diseases, or weeds while minimizing excess usage.

Plant population calculator: Calculate the exact number of seeds required for field crops or plants per unit area in horticulture, ensuring optimal spacing and planting density.

Seed rate calculator: Determine the exact quantity of seeds needed for your farm based on seed test weight and germination rate, ensuring efficient seed usage.

Seed blending calculator: Blend seeds from different lots to prevent waste, using the Karl Pearson square method, helpful for optimizing seed resources and also applicable for wine blending calculations.

VI. Agricultural robots:

Agricultural robots in crop harvesting: Robotic harvesters can pick fruits, vegetables, and other crops with speed and precision. Robotic system uses computer vision to identify ripe fruit and emulates the motion of a human hand while picking apples. These robots are equipped with vision systems to identify ripe produce and robotic arms to delicately harvest them without causing damage.

Tortuga AgTech provides farms with robots that automate tasks like identifying and picking ripe fruit. This robot provides solutions can help to address challenges like labor shortages and rising costs, while also avoiding any damage that might be caused by human hands during the harvesting process.

Agricultural robots in crop weeding: Carbon Robotics' Laser weeder uses AI and computer vision to handle weed control for specialty crops. The mowers are able to differentiate between crops and weeds and then use laser technology to destroy the weeds without causing any damage to the crops.

Conclusion:

Artificial Intelligence has become an essential part of science and technology which plays an important role in precision farming that involves soil mapping, interpretation of vegetation indices and yield prediction. It also helps farmers to monitor crop in order to solve many challenging problems such as nutrient deficiency detection and aid to formulate site specific nutrient management. In short, it is a conglomeration and application of modern advanced science and technology in the field of agriculture.

References:

1. Arnal Barbedo, J.G., (2013). Digital image processing techniques for detecting, quantifying and classifying plant diseases. *SpringerPlus*, *2*(1): 660.
2. Asraf, H. M., Nooritawati, M. T. and Rizam, M. S., (2012). A comparative study in kernel-based support vector machine of oil palm leaves nutrient disease. *Procedia Eng.*, 41:1353-1359.
3. Borhan, M. S., Panigrahi, S., Satter, M. A. and Gu, H., (2017). Evaluation of computer imaging technique for predicting the SPAD readings in potato leaves. *Inf. Process. Agric.*, 4(4): 275-282.
4. Culman, M. A., Gomez, J. A., Talavera, J., Quiroz, L. A., Tobon, L. E., Aranda, J. M., Garreta, L. E. and Bayona, C. J., (2017). A novel application for identification of nutrient deficiencies in oil palm using the internet of things. In *5th IEEE International Conference on Mobile Cloud Computing, Services, and Engineering.* pp. 169-172.
5. Khan, A., (2022). Role of artificial intelligence in insect pest management. Just Agriculture.
6. Prey, L., Von Bloh, M. and Schmidhalter, U. (2018). Evaluating RGB imaging and multispectral active and hyperspectral passive sensing for assessing early plant vigor in winter wheat. *Sensors*, *18*(9): 2931.
7. Richard, A., Domdoma, E.A., Doria, K.A., Ricafranca, K.M., Saito, Y.E., Arago, N., Reyes, R. and Galido, E. (2018). SoilMATTic: Arduino-based automated soil nutrient and pH level analyzer using digital image processing and artificial neural network. In *2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management.* pp. 1-5.
8. Saberioon, M.M., Amin, M.S.M., Aimrun, W., Gholizadeh, A. and Anuar, A.A.R. (2013). Assessment of colour indices derived from conventional digital camera for determining nitrogen status in rice plants. *J. Food, Agri & Envi.*, *11*(2): 655-662.
9. Yuzhu, H., Xiaomei, W. and Shuyao, S. (2011). Nitrogen determination in pepper (Capsicum frutescens L.) plants by color image analysis (RGB). *African J. Biote.*, *10*(77): 17737-17741.

EFFECT OF APPLICATION OF BIOCHAR TO SOIL ON ARTHROPODS

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Abstract:

The global agricultural landscape faces multifaceted challenges in meeting the escalating demand for food due to population growth. To address the projected needs of the world population by 2050, agricultural output must exceed the rate of population growth. However, various factors, including insect pests, contribute to diminished food grain yields, resulting in significant losses. Traditionally, chemical pesticides have been pivotal in managing crop diseases and pests. However, their excessive use has led to ecological and health-related concerns. In response, researchers are exploring alternative approaches, with biochar emerging as a promising solution. Biochar, derived from organic matter pyrolysis, presents a sustainable solution by not only suppressing plant diseases and pests but also enhancing biomass utilization. Its production involves various stages, including drying, torrefaction, exothermic and endothermic pyrolysis, activation, and gasification. Biochar's physical, chemical, and biological properties contribute to improved soil fertility, water retention, nutrient availability, and carbon sequestration. Additionally, biochar applications have been found to reduce greenhouse gas emissions, enhance soil microbial activity, and mitigate soil acidity. Case studies have demonstrated the impact of biochar on insect pest populations and plant responses, highlighting its potential for integrated pest management strategies. However, challenges such as negative effects on soil organisms, delayed plant flowering, and varying responses in different soil types necessitate further

investigation. Future research directions include exploring different feedstocks, optimizing production methods, conducting long-term field trials, assessing interactions with soil microbiota, evaluating climate change mitigation potential, developing biochar-based products, addressing economic viability and policy considerations, and increasing public awareness and outreach efforts. Overall, biochar holds significant promise as a sustainable solution for enhancing soil fertility, managing insect pests, mitigating climate change, and promoting environmental sustainability in agriculture. Continued research and collaborative efforts are essential to harnessing the full potential of biochar and integrating it into sustainable agricultural practices worldwide.

Keywords: Biochar, Pyrolysis, Soil fertility, Crop growth, Insect

Introduction:

The contemporary agricultural landscape grapples with numerous challenges stemming from the escalating demand for food and the steadily increasing global population. Addressing the needs of the projected world population in 2050 necessitates a substantial upsurge in food production to meet the minimum sustenance requirements. Consequently, agricultural output must expand at a rate surpassing the pace of population growth by 2050. Several factors contribute to the diminished yield of food grains, with insect pests emerging as a significant concern among them. These pests inflict substantial losses, accounting for approximately 25 percent in rice, 5-10 percent in wheat, 15 percent in pulses, 20 percent in oilseeds, 20 percent in sugarcane, and 30 percent in cotton (Dhaliwal *et al.,* 2015). Traditionally, chemical pesticides have played a pivotal role in managing crop diseases and insect pests. However, the excessive reliance on synthetic pesticides has led to ecological adversities and health-related issues. In response, researchers have explored alternative approaches, one of which involves biochar. Biochar presents a promising solution as it not only suppresses plant diseases and insect pests but also facilitates the efficient utilization of biomass. Derived from crop residues and other agricultural waste, biochar serves as a valuable soil amendment and nutrient source. By converting organic waste into a beneficial soil enhancer, biochar contributes to the management of soil health and fertility in a sustainable manner.

What is biochar?

Biochar emerges through the pyrolysis process of organic matter like wood and agricultural residues, conducted in oxygen-deprived environments like pits or trenches, at temperatures ranging from 400 to 600°C. This dark gray residue primarily comprises carbon along with residual ash, achieved by extracting water and volatile elements from the initial plant material. It serves as a vital nutrient for plant growth and aids in the synthesis of biochemical compounds essential for plants.

Figure 1: Biochar

Production of biochar

- **Drying and conditioning:**

Biomass primarily comprises five key constituents: cellulose, hemicellulose, lignin, water, and minerals (ash), with proportions varying by source. "Seasoned" wood retains around 12–19% water absorbed within its cellulose/lignin structure. Freshly cut wood or agricultural residues may contain 40 to 60% water content (% wet basis, indicating a percentage of the wet weight of the biomass). Most of this water evaporates as the biomass is heated above 100°C. Beyond 150°C, the biomass undergoes decomposition. At approximately 150°C, the biomass begins to break down and soften, a process known as conditioning. This stage releases chemically-bound water from the biomass molecules, accompanied by minor emissions of carbon dioxide and volatile organic compounds.

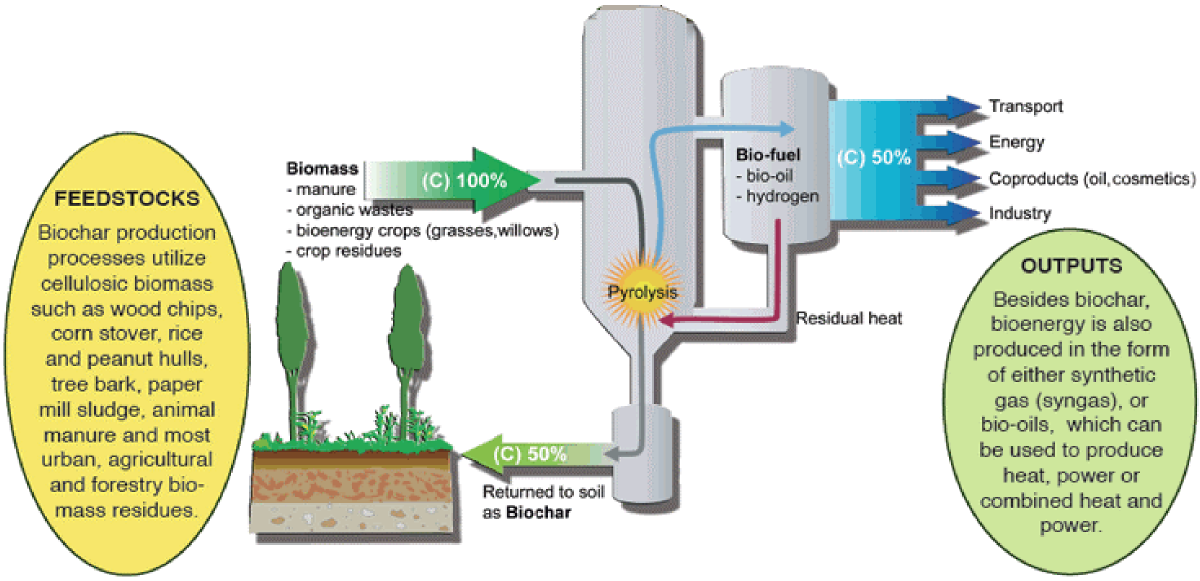

Figure 2: Procedure of biochar production

- **Torrefaction:**

As the biomass undergoes further heating within the temperature range of 200-280°C, chemical bonds within its constituents begin to rupture. This process, known as endothermic, demands heat input to elevate the temperature of the dry biomass and facilitate the breakdown of molecular bonds. During this phase, methanol, acetic acid, and other oxygenated Volatile

Organic Compounds (VOCs) are liberated, alongside emissions of CO_2 and CO resulting from the decomposition of hemicellulose and cellulose. Torrefied biomass exhibits increased brittleness compared to fresh biomass, rendering grinding processes (e.g., for boiler fuel) more facile and less energy-intensive. Moreover, its heightened resistance to biological degradation and water absorption enhances storability. The condensed liquid derived from the vapours of low-temperature pyrolysis, historically referred to as "wood vinegar" or "smoke water," is also recognized as pyroligneous acid. Depending on its concentration and production temperature, it serves various purposes, including but not limited to being utilized as a flavouring agent, fungicide, plant growth stimulant, aid in seed germination, facilitator of composting, and enhancer of biochar effectiveness.

- **Exothermic pyrolysis:**

At temperatures ranging from 250-300°C, depending on the makeup of the biomass being processed, there occurs a heightened thermal breakdown of the biomass, resulting in the release of a combustible blend comprising H_2, CO, CH_4, CO_2, various hydrocarbons, and tars. This phase of pyrolysis becomes exothermic due to the disintegration of the large polymer molecules within the biomass, thereby releasing energy. Concurrently, some oxygen trapped within the biomass structure is liberated, initiating energy-releasing oxidation reactions with the evolving gases and char. The energy liberated fuels the process, facilitating the further rupture of chemical bonds within the biomass. Theoretically, this self-sustaining cycle can persist until temperatures of approximately 400°C, yielding an oxygen-depleted, carbon-rich residue akin to charcoal. However, in practical scenarios, heat dissipation from the pyrolysis zone necessitates external heat input to elevate and sustain the requisite temperature throughout the pyrolysis process. Optimal product yield is typically achieved before the conclusion of the exothermic phase, though the stable carbon content remains relatively modest. For instance, the ash content of wood biochar typically falls within the range of 1.5-5%, with volatiles constituting approximately 25-35% by weight, leaving the balance as fixed carbon at 60-70%.

- **Endothermic pyrolysis:**

After the exothermic pyrolysis process, the residual biochar retains significant amounts of volatile compounds. Additional heating is necessary to enhance its fixed carbon content, surface area, and porosity by expelling and decomposing more of these volatile substances. Typically, raising the temperature to 550-600 °C yields wood biochar with approximately 80-85 % fixed carbon content and a volatile content of around 12 %. At this temperature range, the yield of wood biochar is typically 25-30 % of the weight of the oven-dry feedstock.

Figure 3: Different types of pyrolysis (Irfan *et al.*, 2017)

Figure 4: Biochar made by using different raw materials (Irfan *et al.*, 2017)

- **Activation and gasification**

Once temperatures surpass 600 °C, introducing small amounts of air and steam can elevate the surface temperature of biochar to 700-800 °C, initiating two distinct processes. First, Activation occurs, wherein air, steam, and heat activate the biochar's surface, releasing more volatiles. This enhances surface area and promotes cation exchange by introducing acidic functional groups. Secondly, Gasification occurs when a significant quantity of air and/or steam is added, leading to the production of a relatively clean gas suitable for electricity generation.

However, the biochar yield is typically low, often below 20 %, and accompanied by significant ash content.

Table 1: Nutrient content in biochar as compared to soil and paddy straw (Liu *et al.*, 2021)

Nutrients	Soil	Paddy straw	Paddy straw biochar	SI unit
Total Soil Carbon	17.5	402	418	g kg^{-1}
Total Soil Nitrogen	1.62	7.24	5.80	g kg^{-1}
Total Soil Phosphorous	0.55	1.91	1.20	g kg^{-1}
Total Soil Potassium	28.4	23.3	9.2	g kg^{-1}
pH	5.1	8.5	9.3	---
Bulk Density	1.26	--	0.18	g cm^{-3}
Silicon	1-45	10-17	>20	%

Methods of biochar application

Several methods of biochar application including broadcast and incorporation, banding, spot and ring have been recommended. However, most biochar field trials reported to date have used the broadcast and incorporation method of application.

Effect of biochar application on various factors

- **Soil fertility**: Biochar can improve soil fertility, stimulating plant growth, which then consumes more CO_2 in a positive feedback effect.
- **Reduced fertilizer inputs**: Biochar can reduce the need for chemical fertilizers, resulting in reduced emissions of greenhouse gases from fertilizer manufacture.
- **Reduced N_2O and CH_4 emissions**: Biochar can reduce emission of nitrous oxide and methane, two potent gases from agricultural soils.
- **Enhanced soil microbial life**: Biochar can increase soil microbial life, resulting in more carbon storage in soils.
- **Reduced emissions from feed stocks:** Converting agricultural and forestry wastes into biochar can avoid CO_2 and CH_4 emission otherwise generated by the natural decomposition or burning of the wastes.
- **Energy generation**: The heat energy and the bio-oils and synthetic gases generated during the biochar production can be used to displace carbon positive energy from fossil fuels

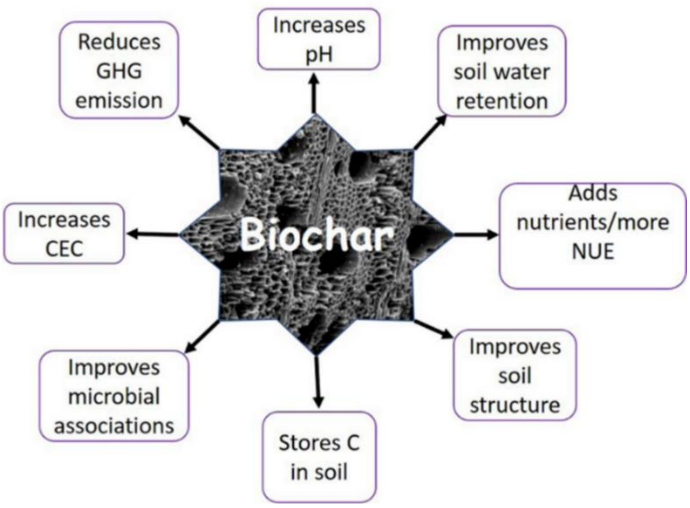

Figure 5: Influence of Biochar on soil properties

Table 2: Application biochar on various factors

Scientists	Results
Kang *et al.*, 2016	Biochar application to soils has been suggested as a potential approach to mitigating greenhouse gas emissions
Laghari *et al.*, 2016	It improves the soil properties
Hou *et al.*, 2022	It is considered as one of the necessary nutrients for plant growth and synthesis of biochemical contents.
Hussain *et al.*, 2017	It increases the plant productivity and it also improves the plant health
Jaiswal *et al.*, 2019	It plays an important part in suppressing the plant diseases
Chen *et al.*, 2020	Biochar amendment to soils can have a negative effect on herbivory by sap-feeding insects.

- Biochar increases nutrient use efficiency.
- Reduces soil nutrients leaching.
- Reduces toxicity of aluminum and iron to plant roots as well as microorganisms.
- Increases runoff water quality, reduces heavy metal bioavailability.
- Due to huge total pore space of biochar, it could retain water in its micro pore space.
- Jasmonic acid (JA) is among the major phytohormones during biotic stress resistance *e.g.*, it releases volatiles to indirectly kill herbivores by attracting its natural enemies or directly by producing toxic compounds to deter invaders (Waqas *et al.*, 2018)
- Jasmonic acid also plays a role in the regulation of important developmental processes (fertility, tendril coiling, sex determination, and leaf senescence).

Disadvantages of biochar

- Biochar aged in soil has negative effects on growth of earthworms and fungi (Anyanwu *et al.,* 2018)
- Biochar application could also result in delay of flowering for plants (Hol *et al.,* 2017)
- Biochar amendment may not necessarily play a positive role for all types of soils (Kavitha *et al.,* 2018)
- Biological aspects of biochar application to a soil, the decomposition of organic matter may be disturbed by the addition of biochar, (Zheng *et al.,* 2016).
- Many studies have reported weed problems when biochar's were applied.

Applying biochar to soils can enrich the organic matter content and enhance soil fertility. Numerous studies indicate that incorporating biochar into soil leads to improved soil texture, increased porosity, better structure, optimal density, and balanced particle size distribution. Due to its high porosity and extensive surface area, biochar provides habitat for beneficial microorganisms and facilitates the binding of essential anions and cations. Multiple research findings support the notion that adding biochar boosts crop growth rates, enhances water quality, reduces nutrient leaching, mitigates soil acidity, improves water retention, and minimizes fertilizer usage. Furthermore, in the presence of supplemented nutrients, plant nutrient uptake substantially increases, resulting in significant growth enhancement upon biochar application to soils.

Mechanisms underlying biochar-induced changes

Biochar-induced changes in soil properties and plant growth are mediated by several mechanisms, which include physical, chemical, and biological processes. Here are some of the key mechanisms underlying biochar-induced changes:

1. Physical properties:

- **Increased water retention:** Biochar has a porous structure that can increase soil water retention capacity, thereby improving water availability to plants, especially in sandy or well-drained soils.
- **Improved soil structure:** Biochar can enhance soil aggregation, leading to improved soil structure and reduced soil compaction. This promotes root growth and allows better penetration of water and nutrients.
- **Increased Cation Exchange Capacity (CEC):** Biochar can increase the soil's ability to retain and exchange positively charged ions (cations) such as calcium, magnesium, and potassium, thus improving nutrient availability to plants.

2. **Chemical Properties:**
   - **Nutrient retention and release:** Biochar can adsorb nutrients such as nitrogen, phosphorus, and potassium, reducing nutrient leaching and making them available to plants over an extended period through slow release.
   - **pH modification:** Depending on its feedstock and production conditions, biochar can modify soil pH, potentially buffering acidic or alkaline soils towards neutral pH, which is optimal for many plants.
   - Reduced Toxicity: Biochar can bind heavy metals and other toxic substances, reducing their bioavailability and potential toxicity to plants.
3. **Biological properties:**
   - **Microbial activity:** Biochar can serve as a habitat for beneficial soil microorganisms, promoting their growth and activity. This includes mycorrhizal fungi, which form symbiotic relationships with plant roots, enhancing nutrient uptake.
   - **Carbon sequestration:** Biochar is a stable form of carbon that can persist in soils for hundreds to thousands of years, effectively sequestering carbon and mitigating greenhouse gas emissions.
   - **Plant growth promotion:** Biochar can stimulate plant growth directly through improved nutrient availability and water retention, as well as indirectly by enhancing soil microbial activity and suppressing plant pathogens.
4. **Interactions with soil components:**
   - **Interactions with clay minerals:** Biochar can interact with clay minerals in the soil, influencing their properties and enhancing soil fertility and nutrient retention.
   - **Adsorption of organic compounds:** Biochar has a high surface area and can adsorb organic compounds such as pesticides and herbicides, reducing their mobility and potential environmental impact.

Overall, biochar-induced changes in soil properties and plant growth are the result of complex interactions between biochar and soil components, as well as feedback loops involving soil microorganisms and plant physiology. These mechanisms vary depending on factors such as biochar feedstock, production conditions, soil type, and environmental conditions.

Case studies

The effect of biochar amendment to soils on *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae) on rice (Chen *et al.*, 2019a)

The application of biochar to soils has the potential to modify soil nutrient dynamics, consequently influencing nutrient uptake by plants. However, the impact of these alterations on leaf-chewing caterpillars has not been thoroughly investigated. This study aims to fill this gap by analysing how varying rates of biochar amendment affect the developmental and reproductive behaviours of the rice leaf-folder, *C. medinalis*, when reared on potted rice plants. Additionally, the study examines changes in the population size of C. medinalis over a two-year period in a paddy field treated with biochar.

Biochar amendment, ranging from 1.5% to 5% of dry weight, was applied to soils, with observations made on larval mortality, development time, body weight, leaf consumption, and fecundity. Results indicate that larval mortality increased with higher biochar levels, while development time and body weight of larvae decreased. Conversely, no significant difference was observed in fecundity across biochar treatments. Additionally, female adult longevity decreased with increasing biochar levels. Field trials revealed a significant reduction in *C. medinalis* population in 2015 with biochar application, although no significant effect was observed in 2016. These findings shed light on the complex interplay between biochar application, soil dynamics, and insect populations, providing valuable insights for agricultural pest management strategies.

Biochar amendment to soils impairs developmental and reproductive performances of a major rice pest *Nilaparvata lugens* (Homoptera: Delphacidae) (Hou *et al.*, 2015)

Biochar amendments to soils have garnered attention for their potential in greenhouse gas mitigation, soil enhancement, and improved crop productivity. However, scant focus has been placed on their impact on herbivorous insect pests. This study investigated how biochar amendments affected the developmental and reproductive performances of the rice brown planthopper (*N. lugens*) on rice plants. The research utilized biochar derived from wheat straw pyrolysis and red-brown soil from a fallow rice field. Results indicated that biochar amendments significantly influenced the nymphal development time, nymph-to-adult survival rate, fecundity, and egg-hatching rate of *N. lugens*. Specifically, higher levels of biochar application led to longer nymphal development time, reduced nymph-to-adult survival, decreased fecundity, and lower egg-hatching rates. Analysis also revealed increases in soil pH, nitrogen, and carbon content with higher biochar levels, while rice plant nitrogen and carbon content decreased. These findings highlight the importance of considering the ecological implications of biochar amendments, particularly regarding arthropod pest dynamics and soil-plant interactions.

Biochar amendment changes jasmonic acid levels in two rice varieties and alters their Resistance to herbivory (Waqas *et al.*, 2018)

The study aimed to determine the optimal biochar level for promoting plant growth in Japonica rice cultivars with varying resistance to White-backed plant hopper (WBPH). It included an additional experiment to assess the impact of biochar-amended substrate on rice cultivars' resistance, measuring endogenous jasmonic acid levels. Results indicated a concentration-dependent effect of biochar on plant growth parameters, with 10% biochar significantly enhancing growth. However, higher concentrations showed inhibitory effects.

Biochar application also influenced plant response to WBPH infestation, with varying effects on different cultivars. Jasmonic acid levels were measured to understand the mechanisms underlying induced systemic resistance. This research highlights the complex interplay between biochar, plant growth, arthropod resistance, and biochemical pathways, shedding light on potential strategies for sustainable agriculture.

Biochar applications decrease reproductive potential of the English grain aphid *Sitobion avenae* and upregulate defense-related gene expression (Chen *et al.*, 2019)

The study investigated the effects of biochar applications on the reproductive potential of the English grain aphid, *S. avenae*, and the upregulation of defense-related gene expression. Biochar, produced through rice straw pyrolysis, was applied to soils at varying levels (0%, 1.5%, 3%, and 5%). Wheat plants and aphids were utilized in the experiment, with aphid fertility and population growth monitored under different biochar treatments. Analysis revealed a significant decrease in aphid lifetime fertility with higher biochar levels, notably by 20.23% at 5%. Aphid population growth was also impacted, with a reduction of up to 28.70% compared to the control. Furthermore, biochar treatments led to increased silicon content in wheat plants, indicating potential alterations in plant physiology.

Molecular analysis showed upregulation of defense-related genes (TaAOS, TaLOX, TaPR, TaPAL) in wheat plants under biochar treatments. These genes play crucial roles in defense pathways against aphid infestation. The expression of these genes increased notably at higher biochar levels, suggesting enhanced plant defense mechanisms. Overall, the study demonstrates that biochar applications can significantly mitigate aphid reproductive potential while enhancing plant defense responses through the upregulation of defense-related genes. These findings highlight the potential of biochar as a sustainable strategy for pest management in agricultural systems.

The effect of amending soils with biochar on the microhabitat preferences of *Coptotermes formosanus* (Blattodea: Rhinotermitidae) (Chen *et al.*, 2022)

The study focused on the impact of biochar on soil and termites. Biochar, derived from rice straw pyrolysis, was added to forest soil. Different concentrations of biochar were tested, from 0% to 20%, with soil moisture adjusted. Termites were collected from a forest and maintained in controlled conditions before experiments. Two types of experiments, selective and non-selective, were conducted to observe termite behaviour in biochar-amended soil. Additionally, a tolerance experiment assessed termite weight and mortality under different biochar concentrations. Soil parameters like pH and humidity were measured. Results indicated that biochar influenced termite abundance, weight, and mortality significantly. Higher biochar concentrations correlated with lower termite numbers and weight but increased mortality. Soil pH increased with biochar concentration, while soil humidity decreased at higher biochar levels. Overall, the study suggests that biochar application alters soil conditions and affects termite behaviour, with potential implications for pest management and soil health.

Differential responses of soil arthropods to the application of biogas slurry and biochar in a coastal poplar plantation (Xu *et al.*, 2022)

Between March 2012 and 2018, an experiment employing a randomized block design with five treatments was conducted within a poplar plantation. The treatments included unfertilized control, low and high levels of biogas slurry (BS), and low and high levels of biochar (BC) applications. The experiment consisted of three replicate blocks, each containing 15 plots. BS was sprayed onto the ground three times a year, while BC was applied once and mixed within the soil layer. Physicochemical attributes of BS and BC were quantified, showing variations in pH, carbon, nitrogen, and nutrient concentrations. Effects of BS and BC applications on total arthropod group number, abundance, and composition were observed. Arthropod abundance increased under BS treatment but decreased under BC treatment. Oribatida and Prostigmata dominated the arthropod communities, with their relative abundances being altered by fertilizer types and dosages. BS application generally increased arthropod abundance, whereas BC application led to decreases.

Correlations between plant, microbial, and physicochemical variables with soil arthropod abundance varied. Total arthropod abundance was positively associated with certain variables like NO_3-N and microbial biomass carbon (MBC) but negatively correlated with soil pH. Similarly, Shannon index was associated with leaf litter biomass and tree diameter at breast height (DBH). The application of BS positively impacted arthropod diversity and community abundance, while BC had negative effects. Changes in tree DBH, biomass production, and soil properties influenced soil arthropod communities directly and indirectly. BS positively affected arthropod abundance directly, while BC had a negative direct effect. Indirect effects were influenced by factors such as urban biomass, soil pH, and microbial biomass carbon. Overall, BS application enhanced arthropod diversity and abundance, whereas BC application led to declines. The study highlights the importance of considering fertilizer type and dosage in managing soil arthropod communities within plantation ecosystems.

Future directions and implications

- **Exploring different feedstocks:** Investigating the potential of various feedstocks for biochar production could provide insights into the diversity of biochar properties and its effects on soil health and plant growth. This includes exploring agricultural residues, forestry waste, and organic waste streams.
- **Optimizing production methods:** Further research is needed to optimize biochar production methods to enhance its properties and efficacy. This involves refining pyrolysis

processes, temperature control, and activation methods to tailor biochar for specific soil and agricultural applications.

- **Long-term studies:** Conducting long-term field trials to assess the persistence and stability of biochar in soil, as well as its long-term effects on soil fertility, carbon sequestration, and crop productivity, is essential for understanding its sustainability and potential impacts on ecosystem functioning.
- **Interactions with soil microbiota:** Investigating the interactions between biochar and soil microbiota, including microbial communities and their activities, can provide insights into the mechanisms underlying biochar effects on soil health, nutrient cycling, and plant-microbe interactions.
- **Climate change mitigation:** Assessing the role of biochar in climate change mitigation by evaluating its potential for carbon sequestration, reducing greenhouse gas emissions, and enhancing soil resilience to climate variability and extreme events.
- **Biochar amendments in various ecosystems:** Expanding research beyond agricultural systems to assess the potential benefits and risks of biochar application in other ecosystems such as forests, grasslands, and wetlands can provide a more comprehensive understanding of its broader ecological implications.
- **Biochar-based products:** Exploring innovative applications of biochar-based products such as biochar-based fertilizers, soil conditioners, and remediation agents for contaminated soils can contribute to sustainable agricultural practices and environmental remediation efforts.
- **Economic viability and policy considerations:** Assessing the economic viability of large-scale biochar production and utilization, including cost-benefit analyses and market potential, is crucial for informing policy decisions and promoting the adoption of biochar as a sustainable soil amendment.
- **Public awareness and outreach:** Increasing public awareness and understanding of biochar and its potential benefits, as well as addressing concerns related to safety, efficacy, and environmental impacts, can facilitate its acceptance and adoption by farmers, land managers, and policymakers.
- **Integration with sustainable agriculture practices:** Integrating biochar application with other sustainable agriculture practices such as organic farming, agroforestry, and conservation agriculture can enhance synergistic effects and promote holistic approaches to soil and ecosystem management.

The future research directions in biochar should focus on optimizing production methods, understanding its long-term effects on soil health and ecosystem functioning, exploring its interactions with soil microbiota, assessing its role in climate change mitigation, developing innovative applications, addressing economic and policy considerations, and increasing public awareness and outreach efforts. These efforts can contribute to harnessing the potential of biochar as a sustainable solution for soil fertility enhancement, climate change mitigation, and environmental sustainability.

Conclusion:

The utilization of biochar as a targeted approach to manage herbivorous pests is gaining traction in research circles. With documented enhancements in soil chemistry, physics, and microbiology due to biochar incorporation, along with increased uptake of essential nutrients and silicon (Si) by plants, it is reasonable to expect that biochar application could indirectly influence pathogen and pest populations on treated plants. Plant responses to herbivory-induced defenses vary widely depending on factors such as herbivore species, plant species and genotype, environmental conditions, and feeding habits. Silicon (Si) is particularly noteworthy among the chemical elements involved in herbivory-induced plant defenses. Silicon contributes to plant resistance against herbivore feeding through two mechanisms: physical resistance (either constitutive or induced) and induced chemical resistance. While the predominant belief has been that solid amorphous silica underpins Si-mediated plant defenses, recent findings suggest the presence of induced physical defense as well. Additionally, Si exhibits similarities to plant stress hormones like jasmonate and salicylate, enabling it to modulate induced resistance, thereby enhancing plants' ability to respond more effectively or rapidly to pathogen or herbivore attacks. Limited studies have suggested that the incorporation of biochar into soils may negatively affect the reproductive potential and population growth of herbivorous pests, while also stimulating induced plant defenses.

References:

1. Anyanwu, I.N., Alo, M.N., Onyekwere, A.M., Crosse, J.D., Nworie, O., & Chamba, E.B. (2018). Influence of biochar aged in acidic soil on ecosystem engineers and two tropical agricultural plants. Ecotoxicology and Environmental Safety, 153, 116-126.
2. Chen, Y., Li, R., Li, B., & Meng, L. (2019). Biochar applications decrease reproductive potential of the English grain aphid, Sitobion avenae and upregulate defence related gene expression. Pest Management Science, 75(5), 1310-1316.
3. Chen, Y., Shen, Y., Li, B., & Meng, L. (2019a). The effect of biochar amendment to soils on Cnaphalocrocis medinalis Guenee (Lepidoptera: Pyralidae) on rice. Journal of Crop Protection, 124, 104-110.
4. Chen, Y., Zhao, C., Zhang, D., Zhang, S., Zeng, W., & Li, Z. (2022). The effect of amending soils with biochar on the microhabitat preferences of Coptotermes formosanus (Blattodea: Rhinotermitidae). Ecotoxicology and Environmental Safety, 232, 1-9. doi.org/10.1016/j.ecoenv.2022.113240.

5. Chen, Y., Rong, X., Fu, Q., Li, B., & Meng, L. (2020). Effects of biochar amendment to soils on stylet penetration activities by aphid Sitobion avenae and plant hopper Laodelphax striatellus on their host plants. Pest Management Science, 76(1), 360-365.
6. Dhaliwal, G.S., Jindal, V., & Dhawan, A.K. (2010). Insect pest problems and crop losses: changing trends. Indian Journal of Ecology, 37(1), 1-7.
7. Hol, W.G., Vestergård, M., Ten Hooven, F., Duyts, H., van de Voorde, T.F., & Bezemer, T.M. (2017). Transient negative biochar effects on plant growth are strongest after microbial species loss. Soil Biology and Biochemistry, 115, 442-451.
8. Hou, X., Meng, L., Li, L., Pan, G., & Li, B. (2015). Biochar amendment to soils impairs developmental and reproductive performances of a major rice pest Nilaparvata lugens stal. (Homoptera: Delphacidae). Journal of Applied Entomology, 139(10), 727-733.
9. Hou, J., Pugazhendhi, A., Sindhu, R., Vinayak, V., Thanh, N.C., Brindhadevi, K., Chi, N.T.L., & Yuan, D. (2022). An assessment of biochar as a potential amendment to enhance plant nutrient uptake. Environmental Research, 214, 113909.
10. Hussain, M., Farooq, M., Nawaz, A., Al-Sadi, A.M., Solaiman, Z.M., Alghamdi, S.S., Ammara, U., Ok, Y.S., & Siddique, K.H. (2017). Biochar for crop production: potential benefits and risks. Journal of Soils and Sediments, 17, 685-716.
11. Irfan, M.R., Kaleri, F.N., Rizwan, M., & Mehmood, I. (2017). Potential value of biochar as a soil amendment: A review. Pure and applied biology (PAB), 6(4), 1494-1502.
12. Jaiswal, A.K., Graber, E.R., Elad, Y., & Frenkel, O. (2019). Biochar as a management tool for soilborne diseases affecting early-stage nursery seedling production. Crop protection, 120, 34-42.
13. Kang, S.W., Park, J.W., Seo, D.C., Ok, Y.S., Park, K.D., Choi, I.W., & Cho, J.S. (2016). Effect of biochar application on rice yield and greenhouse gas emission under different nutrient conditions from paddy soil. Journal of Environmental Engineering, 142(10), 04016046.
14. Kavitha, B., Reddy, P.V.L., Kim, B., Lee, S.S., Pandey, S.K., & Kim, K.H. (2018). Benefits and limitations of biochar amendment in agricultural soils: A review. Journal of environmental management, 227, 146-154.
15. Laghari, M., Naidu, R., Xiao, B., Hu, Z., Mirjat, M.S., Hu, M., Kandhro, M.N., Chen, Z., Guo, D., Jogi, Q., & Abudi, Z.N. (2016). Recent developments in biochar as an effective tool for agricultural soil management: a review. Journal of the Science of Food and Agriculture, 96(15), 4840-4849.
16. Liu, J., Jiang, B., Shen, J., Zhu, X., Yi, W., Li, Y., & Wu, J. (2021). Contrasting effects of straw and straw-derived biochar applications on soil carbon accumulation and nitrogen use

efficiency in double-rice cropping systems. Agriculture, Ecosystems and Environment, 311, 107286.

17. Waqas, M., Shahzad, R., Hamayun, M., Asaf, S., Khan, A.L., Kang, S.M., Yun, S., Kim, K.M., & Lee, I.J. (2018). Biochar amendment changes jasmonic acid levels in two rice varieties and alters their resistance to herbivory. PLoS One, 13(1), 1-18. doi.org/10.1371/journal.pone.0191296.
18. Xu, H., Long, Q., Sun, Y., Wang, R., Zou, X., & Ruan, H. (2022). Differential responses of soil arthropods to the application of biogas slurry and biochar in a coastal poplar plantation. European Journal of Soil Biology, 113, 1-8. doi.org/10.1016/j.ejsobi.2022.103447.
19. Zheng, J., Chen, J., Pan, G., Liu, X., Zhang, X., Li, L., Bian, R., Cheng, K., & Jinwei, Z. (2016). Biochar decreased microbial metabolic quotient and shifted community composition four years after a single incorporation in a slightly acid rice paddy from southwest China. Science of the Total Environment, 571, 206-217.

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RAPESEED AND MUSTARD PRODUCTION: CULTIVATION, CHALLENGES, AND OPPORTUNITIES

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Abstract:

Rapeseed and Mustard Production: Cultivation, Challenges, and Opportunities offers a comprehensive exploration of the cultivation practices, challenges, and opportunities surrounding rapeseed and mustard crops. These oilseed crops are of immense importance globally, serving as sources of edible oil, biofuel, and industrial applications. The abstracted book provides insights into various aspects of rapeseed and mustard production, including their botanical classification, agronomic considerations, cultivation techniques, and post-harvest management. It delves into the historical significance of these crops, their genetic diversity, and their adaptation to different agro-climatic conditions. Additionally, the book addresses the challenges faced by growers, such as pest and disease pressures, environmental stresses, and market volatility, while proposing strategies for sustainable production and enhanced profitability. With its focus on research advancements, technological innovations, and best practices, this book serves as a valuable resource for researchers, agronomists, farmers, policymakers, and industry professionals involved in rapeseed and mustard cultivation and utilization.

Introduction:

Rapeseed and mustard are significant oilseed crops globally, contributing to food security, economic development, and sustainable agriculture. The cultivation of these crops spans diverse agro-climatic regions, offering a wide range of opportunities and challenges for growers, researchers, and policymakers. "Rapeseed and Mustard Production: Cultivation, Challenges, and Opportunities" presents a comprehensive exploration of the intricacies surrounding the production of these vital crops. This book aims to provide a holistic overview of rapeseed and mustard cultivation, addressing various facets from botanical classification to post-harvest management. It delves into the historical background of these crops, tracing their evolution and adaptation to different regions across the world. Additionally, the book explores the genetic diversity within rapeseed and mustard species, highlighting their resilience and adaptability to changing environmental conditions. The cultivation practices of rapeseed and mustard are multifaceted, encompassing aspects such as land preparation, seeding techniques, nutrient management, and pest control strategies. This introduction sets the stage for a deeper dive into these agronomic considerations, aiming to equip growers with the knowledge and tools necessary for successful crop production. Furthermore, the book addresses the challenges encountered by rapeseed and mustard growers, ranging from pest and disease pressures to market volatility and environmental stresses. By elucidating these challenges, the book aims to foster discussions around potential solutions and innovative approaches to enhance the resilience and sustainability of rapeseed and mustard production systems. In light of the growing demand for edible oils, befouls, and industrial applications, rapeseed and mustard hold immense promise as valuable crops for global agriculture. This book seeks to shed light on the opportunities that exist within the rapeseed and mustard sector, including technological innovations, market expansion, and value-added product development. In conclusion, "Rapeseed and Mustard Production: Cultivation, Challenges, and Opportunities" serves as a comprehensive resource for stakeholders across the rapeseed and mustard value chain. By synthesizing research findings, best practices, and practical insights, the book aims to contribute to the advancement of sustainable rapeseed and mustard production, thus ensuring the continued prosperity of these vital crops in the agricultural landscape.

Rapeseed and mustard

Rapeseed (*Brassica campestris*) and Mustard (*Brassica juncea*) are the major rabi oilseed crops of India. India is one of the largest producers of these crops in the world. The production of rapeseed and mustard in India accounts for about 18% of the total oilseed production of the country. Sarson and toria (lahi) are generally termed as rapeseed, rai or raya or laha is termed as mustard. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout northern India in cooking and frying purposes. The oil cake is used as a cattle feed and manure. Green stems and leaves are a good source of green fodder for cattle. The leaves of young plants are used as green vegetables as they supply enough sulphur and minerals in the diet.

The oil content of the rapeseed and mustard ranges from 30 to 48 percent. The crop is grown both in subtropical and tropical countries. Among the rabi oilseeds, rapeseed and mustard can play an important role in the north eastern hill region to boost oilseed production. In the region, rapeseed-mustard can be successfully grown as rabi crop up to mid altitude (<1300 m msl) and yield level of 8-12 q/ha can be achieved by adopting improved production technology.

In NEH region, rapeseed - mustard is cultivated in an area of 0.46 lakh ha and the average yield is 888 kg/ha, which is much lower compared to the national average (941 kg /ha). The low productivity is primarily due to untimely sowing, poor crop stand, inadequate nutrition, moisture stress and almost no plant protection measures. The problems get further aggravated when the crop is cultivated on marginal land under rainfed conditions.

Mustard in field and terraces

Climate

Rapeseed and mustard are crops of tropical as well as temperate zones and require somewhat cool and dry weather for satisfactory growth. They require a fair supply of moisture during the growing period and a dry clear weather at the time of maturity. Cool temperature, clear dry weather with plentiful of bright sun shine accompanied with adequate soil moisture increases the oil yield. In India they are grown in Rabi season from September-October to February-March. Toria is more liable to suffer from frost and cold and is, therefore, usually sown earlier and harvested before the onset of frost. Rape seed and mustard are long day crops in photo-periodic response. These crops are not drought tolerant. They require an annual precipitation of 350-450 mm.

Soil

Rapeseed and mustard are capable of growing under a wide range of soil conditions varying from sandy loam to clay loam soils but they thrive best on light loam soils. They neither tolerate water logging conditions nor do well on heavy soils. Plants can tolerate moderate salinity reasonably well but a soil having neutral pH is ideal for their proper growth and development.

Varieties

ICAR Research Complex for NEH Region has developed four yellow sarson lines viz. TRS –Y- 01-5-1-1 (1.6 1 t/ha), TRS –Y-01-2-2-1 (1.3 t/ha), SCRT 1-2-1 and SCRT 1-2-3 (1.64 t/ha).

State-wise major varieties of mustard & rapeseed

State	Cropping systems
Meghalaya	M-27, TS-36, TS-46
Manipur	M-27, TS-36
Mizoram	Kranti, TS-36, TS-46
Nagaland	TCN-42, M-27, TS-38
Sikkim	Sikkim Sarson, M-27, Kranti
Tripura	TM-6, Kranti, M-27, TS-38

Cropping systems:

Generally, in the NEH region, the rainfall ceases in the last week of September and moisture stress starts after November, which is not suitable for taking rabi crop. If short duration varieties of rapeseed and mustards, which mature in 90-100 days, are sown after harvest of upland rice and maize, not only the cropping intensity would be increased but the production of oilseeds also will be increased. Under high moisture condition in low, wet and marshy lands where rabi crop is not possible due to excessive moisture, the permanent or temporary raised and sunken beds opens up new vistas for growing any crop including oilseeds during rabi season.

The inclusion of rapeseed and mustard in cropping systems on raised beds increase the production and productivity of oilseeds. The adoption of intercropping system on raised bed although decreased the productivity of individual crop but overall system productivity increases markedly.

The following cropping systems have been identified for the NEH region -

Mid and low altitude (a) Dry upland terraces

Maize-mustard,

Maize + French bean-mustard

Rice – mustard, French bean - mustard

Groundnut – mustard

Marshy/lowland/wetland conditions (raised beds)

Maize-mustard,

Rice-mustard

Rice-mustard-tomato,

Rice-mustard-potato

Groundnut- mustard

Intercropping on raised beds

Cabbage + mustard,

Broccoli + mustard

Coriander + mustard

Field preparation

A clean and well pulverised seedbed of good tilth is needed for better germination. The land should be well prepared first by ploughing deep with soil turning plough, followed by two cross harrowing. Each ploughing should be followed by planking so that the soil is well pulverised and leveled. Care should be taken to see that weeds and stubbles are removed from the field and the soil contains adequate moisture to ensure good germination. Zero tillage cultivation of toria after rice and maize is a viable proposition which saves time, energy and reduces cost of cultivation. Immediately after rice harvest, a narrow furrow should be opened in between two rice rows with the help of furrow opener and the manure should be applied and the sowing of seeds should be undertaken followed by covering of the seeds.

Mustard Flower

Seed and sowing:

Time of sowing

Planting time is the single most important variable affecting the seed yield of rape seed and mustard to a great extent. Since the rate of development of oil in seed is greatly influenced by the variation in atmospheric temperature, humidity, and other biotic factors, sowing either too early or too late have been reported to be harmful. Delay in planting reduces the yield on account of its depressing effect on the plant growth, flowering duration, seed formation and seed size. Therefore, for getting good yields of rape and mustard timely sowing is a must. Toria should be sown from the mid to the last week of September. If sowing of toria is delayed, there is great danger of attack of aphids on the crop. Sowing of sarson and rai must be completed in the first fortnight of October.

Seed rate and spacing

Spacing has no absolute value in the cultivation of rape and mustard as it fluctuates a great deal with the growth habit of variety, date of sowing, manuring and irrigation practices. Generally toria is planted in rows 30 cm apart while sarson and rai are sown in rows 45 cm apart. Thinning is done three weeks after sowing to maintain a plant to plant distance of 10 to 15 cm. In case of mixed cropping they are generally sown in rows 1.8 to 2.4 meters apart in the main crop, 5 to 6 kg seed should be sown in rows at a depth of 2.5-3.0 cm in case of a pure crop. When sown mixed with some other crop, 1.5 to 2 kg seed per hectare is sufficient. Sowing could be done either behind the local plough or through seed drill.

Manures and fertilizers

Apply 10 tones of farm yard manure or vermicompost @ 5t/ha during last field preparation along with 150 kg rock phosphate.

Water management

Normally, no irrigation is required in the rapeseed-mustard as it is sown on residual soil moisture and it receives one or two showers during October and November months. However, in case of moisture stress, one irrigation at flowering is required to obtain good yield. Irrigation increases yield of rapeseed and mustard significantly. In agro- climatic conditions of Meghalaya, irrigation at 0.3 IW/CPE ratio produced significantly higher seed yield followed by 0.6 IW/CPE ratios. Flowering and siliqua formation stages are critical stages for irrigation in rapeseed and mustard. Two irrigations at pre-bloom and pod filling stages are beneficial.

Weed management

Weeds in rape and mustard crop cause approximately 20-30 percent reduction in yield. Care should be taken to remove all weeds in the early stages of crop growth to avoid competition on the reserve of moisture. One intercultural operation with hand hoe is very beneficial. This, besides creating soil mulch also reducing moisture losses through evaporation and helps in better growth and development of crop plants. Thinning operation helps in better growth and development of crop plants. Thinning operation should be accompanied with inter-culture to provide the plants proper space within the rows. Major weeds observed in rapeseed and mustard field are Bidens pilosa, Ageratum conyzoides, Chenopodium album, Euphorbia hirta etc. Hand weeding at 30 and 60 days after sowing has recorded maximum seed yield.

Plant protection

The most serious insect-pest of mustard is aphids. While white rust and Alternaria blight are two important diseases of rapeseed and mustard in the region. Symptoms and management practices for insect pest management and diseases are as follows:

Mustard aphids (*Lipaphis erysimi*)

Symptoms – Both nymphs and adults suck the sap from leaves, buds and pods. Curling may occur in infested leaves and at advanced stage plants may wither and die. Plants remain stunted and sooty moulds develop on the honey dew excreted by the insects. The infected filed looks sick and blighted in appearance.

Mustard Aphids

Management

Cultural – Use tolerant varieties, early planting to escape the dmage and use of yellow sticky traps.

Biological – Release, protection and promotion of beneficial insects such as, adybird beetles viz., Coccinella septempunctata, Menochilus sexmaculata, Hippodamia variegata and Cheilomones vicina are most effcient pradators of the mustard aphid. Adult beetle may feed an average of 10 to 15 adults/ day. Several species of syrphid /hover fly i.e., Sphaerophoria sp., Eristallis sp., Metasyrphis sp., Xanthogramma sp and Syrphus spp. The braconid parasitoid, Diaeretiella rapae. The lacewing, Chrysoperla zastrowisillemi.

Control measure – 2-3 spray of soft soap or insecticidal soap as soon as the aphids start appearing. 2% neem oil or 5% NSKE is also very effective in aphid's management. Foliar spray of Verticillium lecanii @ 5 gm/ lit of water. In severe infestation garlic-chilly extract with 2% neem oil and liquid soap is very effective.

Painted bug (*Bagrada hilaris*)

Symptoms – Both nymphs and adult suck sap from leaves and pods which in due course wilt and show symptoms of withering. Adult bugs secrete gummy substance which spoils the pods.

Management

Cultural – Deep ploughing. Early sowing helps in avoiding the pest attact. Irrigation during first 4 weeks also help in its management. Bugs generally congregate on leaves and stem. By jerking the plants and leaves bugs can be dislodged and collected from ground for destruction. Burn crop remains of infested field to destroy eggs and other stages to prevent their spread in next year's crop.

Biological - Conserve and promote egg parasitoid Gryon sp. (Scelionidae) and the adult parasitoid Alophora sp. (Tachinidae).

Control measures – Seed treatment with cow urine and garlic-clove-cinnamon extract help in managing bug during initial growth phase. Prophylactic sprays of neem+karanj oil with insecticidal soap through pressure jet on leaves and stem also help in control of pest.

Painted bug (left) and Sawfly (right)

Mustard Sawfly (*Athalia lugens proxima*)

Symptoms - In initial stages of infestation larva nibbles leaves, later as it grows it start feeding the leaves from margins towards the midrib. Numerous shot holesare visible, sometimes the entire leaves get riddled by voracious feeding. Grub prefers epidermis of the shoot, resulting in drying up of seedlings and failure to bear seeds in older plants.

Management

Cultural - Summer ploughing to destroy the pupa. Early sowing helps in avoiding the pest problem. Maintain clean cultivation. Give irrigation in seedling stage is very crucial for sawfly management because most of the larvae die due to drowning effect. Severe cold reduces pest load. Collection and destruction of grubs of saw fly in morning and evening

Biological - Conserve Perilissus cingulator (parasitoids of the grubs), foliar spray of pathogenic bacteria Serratia marcescens which infect the larvae of sawfly.

Control measure - Foliar spray of bitter gourd seed oil (5%) can effectively manage the sawfly.

White rust/ Downy mildew (*Albugo candida*)

Symptoms – White, creamy pustules emerge on the stem, twig and leaf surfaces. In systemic infection such whilte rusty pustules emerge on all parts of the body and induce hypertrophy (abnormal enlargement of cells). In secondary local infection white rusty pustules emerge on leaf, stem and inflorescence and give powder coated appearance.

Management

Cultural – Use disease free, healthy seed, destroy weeds which act as collateral host, collect and destroy infected plant parts. In cases of consistent problem areas adopt 3-4 years long crop rotation with non-host crops.

Control measures – Seed treatment with freshly prepared garlic bulb extract. Alternatively, seeds can also be treated with garlic-clove-cinnamon extract. Foliar spray of Bordeaux mixture (1%) or copper oxychloride (0.3%) can also manage the pest.

White rust (left) and Alternaria leafs pot (right)

Alternaria leaf spots (*Alternaria brassicicola* and *A. brassicae*)

Symptoms – Dark coloured leaf spots with concentric rings emerge. Spots of A. Brassicicola are larger in size while that of A. Brassicae are small in size. Leaf tissue dries up and drop-off, leaving big irregular holes.

Cultural – Maintain field sanitation, Adopt 3-4 years long crop rotation with non- host crops. Early sowing escapes the infection

Control measures – Seed treatment with hot water (50oC) or with freshly prepared garlic bulb extract. Alternatively, seeds can also be treated with garlic- clove-cinnamon extract. Foliar spray of copper oxychloride (0.3%) at an interval of 15 days from 45 days after sowing can effectively manage the pest.

Harvesting and Threshing

As soon as the pods turn yellowish-brown, harvest the crop. Normally, the crop is ready for harvest after 90 - 105 days of sowing. Preferably, harvesting should be done in the morning hours to avoid shattering loss. The crop is liable to shattering, hence it should be harvested just before the pods open in order to avoid losses. Sarson is less liable to shattering as compared to toria and mustard. Crop is harvested with the help of sickles. The harvested crop should be stacked in threshing floor for five to six days before threshing. Threshing is very easy with the help of sticks. The pods easily shatter and give away seeds. Threshing could be done with bullocks or tractor. The threshed grain is separated from the husk with the help of slow moving natural air current. Cleaned seed must be dried in the sun for four to five days or till the moisture content comes down to 8 percent.

Yield

With the use of improved varieties, agronomical and plant protection techniques, the farmers may expect to harvest a seed yield of about 10-15 q/ha.

Mustard seeds

References:

1. Ahuja, I., & Srinivasan, K. (Eds.). (2019). Rapeseed Breeding: Advances in Botanical Research. Academic Press.
2. Gupta, R. K., & Srinivasan, K. (Eds.). (2018). Mustard Production and Processing

Technology. CRC Press.

3. Hocking, P. J. (2012). Responses of canola (Brassica napus L.) to drought and high temperature stress: yield and water use efficiency, adaptation, and stress resistance. Agricultural Water Management, 104, 11-23.
4. Kaur, P., & Banga, S. S. (2018). Mustard Breeding: Challenges and Opportunities. In Oilseed Brassicas: Constraints and Their Management (pp. 133-151). Springer.
5. Rahman, M. H., Hasanuzzaman, M., & Nahar, K. (2017). Mustard: A Potential Oilseed Crop. In Achieving Sustainable Cultivation of Oilseeds (Vol. 1, pp. 165-183). Burleigh Dodds Science Publishing Limited.
6. Rahman, M. H., Hasanuzzaman, M., & Nahar, K. (Eds.). (2019). Mustard Improvement: Achievements and Challenges. Springer.
7. Suresh, P., & Srinivasan, K. (Eds.). (2016). Rapeseed and Mustard: Production, Processing, Food Quality, and Nutrition. CRC Press.
8. Upadhyaya, H. D., & Bisht, I. S. (2012). Genetic resources of mustard: diversity, conservation, and utilization. Genetic Resources and Crop Evolution, 59(7), 1077-1088.
9. Wani, S. H., Kumar, V., & Shriram, V. (Eds.). (2019). Molecular Breeding for Sustainable Crop Improvement: Volume 2. Springer.
10. Yadava, D. K., & Rao, T. P. (Eds.). (2018). Advances in Rapeseed Production: Constraints and Management. CRC Press.

BIODIVERSITY LOSS: CURRENT AND FUTURE THREATS

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Abstract:

Each living organism encounters a novel array of challenges, exerting an influence on ecosystems as a whole annually. There exist certain knowledge gaps pertaining to environmental hazards that hinder the optimal growth and proliferation of flora and fauna. Consequently, the gradual depletion of biodiversity is observed, with tens of thousands of species facing the imminent risk of extinction due to both anthropogenic activities and natural calamities. This unfortunate situation poses a significant obstacle to global economic development and overall progress. In this analysis, we delve into the perils faced by biodiversity in the face of extinction, aiming to prevent any further loss of biodiversity in the future. It is predicted that the expansion of growth and economic development will introduce unparalleled levels of risk, endangering numerous species on a global scale. However, it is important to note that certain threats to our environment can be mitigated through proactive international initiatives. By focusing on the protection of natural habitats in developing countries, we have the potential to safeguard a significant portion of Earth's remaining biodiversity.

Keywords: Ecosystem, Biodiversity, Extinction, Threats, Future Biodiversity

Introduction:

The scientific concept of "Diversity" pertains to the extent of variation or dissimilarities among a given set of characteristics. In the context of the natural world, "biological diversity" encompasses the assortment of life forms and the differences that exist within and between them. As per the definition provided by the Parties to the Convention on Biological Diversity (CBD), biodiversity encompasses the range of differences among living organisms originating from various habitats such as terrestrial, marine, and other aquatic ecosystems, as well as the ecological systems they form a part of. This includes the diversity that exists within species, between species, and across ecosystems. The biodiversity of our planet is dependent upon variations in specific elements, serving as the fundamental constituents and building blocks of biological diversity. This diversity is expressed and manifested in a multitude of ways, as illustrated in Table 1.

Table 1: Elements of Biodiversity

Ecological diversity	Genetic diversity	Organismal diversty
Biomes	Populations	Domains of Kingdoms
Bioregions	Individuals	Phyla
Landscapes	Chromosomes	Families
Ecosystems	Genes	Genera
Habitats	Nucleotides	Species
Niches		Subspecies
Populations		Populations
		Individuals

Based on the elements involved, the concept of biodiversity focuses on assessing the degree of variation at three distinct levels:

1. Within-species (Intra-specific) variation - encompasses both genetic diversity and population-level metrics, collectively referred to as genetic variability. The biological makeup of an organism includes genetic components such as nucleotides, genes, and chromosomes. These components serve as the structural foundation of the organism and can vary between individuals within a population and between populations. Genetic variation can manifest in the form of allelic differences, variations in entire genes, or alterations in chromosomal structures. Enhanced adaptation of species to the altered environment is facilitated. The emergence of novel species can be attributed to genetic diversity.

2. Inter-species (Between species) diversity - encompasses all forms of variation observed at the level of species, commonly referred to as species diversity or organismal diversity. It pertains to the taxonomic classification system, including its hierarchical structure and constituent parts, ranging from the individual level to that of species, genera, and beyond. The quantification of species diversity is achieved through the utilisation of two metrics: species richness, which denotes the number of species present within a given unit area, and evenness or equitability, which pertains to the uniformity in the distribution of individuals among the various species. Regarding species richness, a higher level of species diversity indicates a greater variety of species. In the second scenario, the even distribution of species indicates a greater level of biodiversity.

3. Within ecosystems - In the context of ecosystems, the concept of diversity can be examined at a landscape or regional scale, commonly referred to as ecosystem or ecological diversity. This pertains to the range of variations observed in the biological communities that support the various species within the ecosystem highlighting the ecological variations across different levels, ranging from individual populations, niches, and habitats to larger biomes. Alpha diversity refers to the range of species present within a given ecological community. It is a measure of the mean species diversity within a given habitat or geographical location which is used as a metric that characterizes the diversity of species within a particular ecosystem or habitat. It is typically used as a local measure to assess the number and abundance of species within a specific area. Beta diversity refers to the variability in species composition among different ecological communities. It pertains to the proportion of regional diversity in relation to local or alpha diversity and is used to describe the variation in species composition between two distinct habitats or regions is known as species diversity. The quantification of the variety of habitats across a given landscape or geological expanse is commonly known as Gamma diversity which is the total Landscape diversity in the field of environmental science i.e. combination of both alpha and beta diversity. The concept of gamma diversity refers to the comprehensive diversity of a given ecosystem, which is a composite of both alpha and beta diversity. The current biodiversity has undergone millions of years of evolutionary processes, thus it is crucial to maintain ecological equilibrium and avoid any disruptions. Various types of ecosystems exist, such as forest ecosystems, aquatic ecosystems, grasslands, deserts, and mangroves.

Persistent threats to biodiversity

A threat is defined as any process or event that may result from various direct or indirect drivers of natural or anthropogenic origin, leading to modifications and detrimental impacts on the condition or sustainable utilization of any aspect of biodiversity. A primary factor that significantly impacts ecosystem processes is a direct driver. Indirect drivers have a diffuse impact as they modify one or multiple direct drivers. The primary direct factors that significantly impact biodiversity include the modification of habitats, climate change, and the introduction of invasive species, in addition to overexploitation and pollution. The planet's biodiversity is experiencing a rapid decline as a result of various factors, including land use changes that lead to habitat alteration and destruction, overexploitation of biological resources, pollution, invasive species, and climate change. Various natural and anthropogenic factors have a tendency to interact and exhibit positive feedback mechanisms. Anthropogenic activities have significantly impacted the environment, resulting in accelerated changes that have disrupted ecosystem processes (Prakash and Verma, 2022). This has led to severe environmental degradation, with no indication of abatement in the past, present, or future. The rate of species extinction has increased rapidly in recent years, which is in stark contrast to the gradual pace of extinction observed in the past. While species extinction is a natural phenomenon, human activities have significantly accelerated the rate of extinction to at least 100 times the natural rate in Earth's history. The ongoing trend of decreasing animal and plant populations is a concerning issue in terms of their geographic distribution. The current scientific consensus suggests that the rate of extinction is estimated to be around 10,000 species per year. This phenomenon is a cause for concern in terms of its impact on biodiversity. If this pattern persists, it is projected that between one-third and two-thirds of existing biodiversity will face extinction by the mid-21st century (IUCN, 2020).

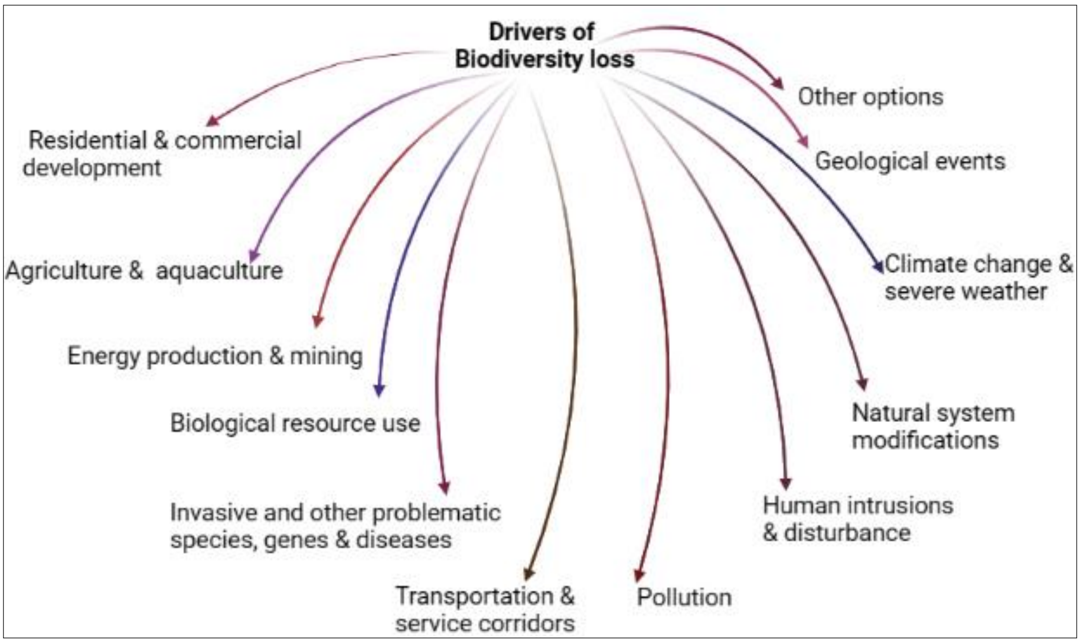

Figure 1: Persistent main drivers of biodiversity loss

1. Residential and commercial development: The peril of residential and commercial development encompasses the establishment of human habitation, such as cities and towns, as well as non-agricultural land utilization that leaves a significant ecological impact. The phenomenon under consideration encompasses the process of habitat conversion, which is intricately linked to the initial stages of development, such as deforestation, filling/excavation, and drainage activities. Additionally, it encompasses the utilization, upkeep, and subsequent consequences of infrastructure, including incidents like birds colliding with windows. As a result of the exponential growth and movement of the human population, it is projected that approximately 2 billion individuals will inhabit urban areas by the year 2030. However, the implications of both present and forthcoming urbanization on the preservation of biodiversity remain inadequately understood (Veach, 2017). The expansion of urban areas has a profound impact on eco-regions, particularly those that are home to rare species and protected areas with limited geographical distribution. Presently, it has been observed that out of the 825 eco-regions across the globe, a total of 29 eco-regions are experiencing urbanization on more than one-third of their total area. These specific eco-regions serve as the exclusive habitat for a noteworthy count of 213 endemic terrestrial vertebrate species. The expansion of urban areas persists and propelled by the growth of urban populations in developing nations and the low population density found in newly urbanized regions of the developed world (Jackson, 1985, Liu *et al.*, 2003, Angel *et al.*, 2005). The extensive process of urbanization is anticipated to exert substantial impacts on the natural environment and its capacity to provide essential services to mankind (Bolund and Hunhammar, 1999; McGranahan *et al.*, 2006; Forman, 2008). These effects can be observed both directly as urban areas expand and indirectly as a consequence of shifts in consumption patterns and pollution levels resulting from rural-to-urban migration

(McKinney, 2002; Liu *et al.*, 2003; McGranahan and Satterthwaite, 2003). Several activities are delineated as follows:

1.1 Housing & urban areas: Everything that is connected to or integrated with urban or housing structures is referred to as housing or urban regions like urban areas (cities), suburbs, villages, cottages, offices, commercial districts, institutions of higher learning, and public parks. Dense housing and urban areas: These are places with medium- to high-density residential development and structures housing associated services permits little to no upkeep of natural processes for instance, cities, suburbs, towns, hospitals, schools, and libraries. Low-density living areas: These are residential regions with significant development (including resorts), where the spacing permits some continuation of ecological services. Particularly in rural and agro-forestry settings, this form of development is evident. For instance, homes in rural locations, cottages, holiday properties next to water, ecotourism inns, fishing lodges, and backcountry ski inns. Urbanisation leads to the detrimental consequences of natural habitat loss, degradation, and fragmentation. Additionally, it brings about an escalation in impervious surfaces, which exacerbates the environmental impacts associated with further disrupting the delicate balance of the environment (Theodorou, 2022). In essence, the process of urbanisation gives rise to the formation of unique ecosystems that display distinctive abiotic and biotic features, presenting a formidable obstacle for numerous organisms.

1.2 Commercial and industrial constructions: these activities are connected and integrated with these spaces, which are also designated locations for storing garbage including animal scare tactics, which are required close to specific infrastructure for example, industrial parks, factories, workplaces, malls, all military base installations, power plants, airports, and seaports and shipyards.

1.3 Open dump sites are outdoor facilities: These sites are utilized for the purpose of waste disposal or temporary storage of materials before they undergo recycling processes. These sites are mostly anthropogenic that includes automobile junkyards, metal recycling centers, landfills, and nuclear waste disposal facilities. These locations are of particular concern with the aim to understand the ecological consequences and develop strategies to mitigate any negative effects they may have on, their potential impact on the surrounding ecosystems and the environment as a whole (Mohan and Joseph, 2021).

1.4 Areas of tourism and recreation: Touristic destinations or recreational establishments are the areas that possess a substantial ecological impact, excluding any structures designated for residential purposes. The designated areas for parks and sports fields serve as crucial habitats for various organisms, contributing to the overall biodiversity and ecological balance of the surrounding environment. These spaces provide essential resources, such as food, water, and shelter. These areas undergo intensive management practices, such as regular grass-cutting and woodland thinning, with the primary objective of facilitating recreational activities. These activities typically include leisurely walks in urban parks and engaging in various sports. Additionally, this encompasses outdoor locations that are carefully maintained for the purpose of prayer or mourning, such as cemeteries, expansive areas that undergo regular mowing and maintenance to facilitate recreational activities such as walking, picnicking, engaging in children's play, and even providing spaces for mourning, as observed in cemeteries. Additionally, these spaces may also serve as venues for various sports activities including golf, both traditional and miniature versions, as well as soccer, American football, baseball, basketball, and tennis, thereby catering to a wide range of athletic pursuits. Campgrounds Locations that are designated and upheld for the purpose of engaging in camping endeavors, wherein the amenities provided possess the potential to exert certain ecological ramifications. In order to differentiate it from wilderness camping devoid of amenities, For instance, the availability of car or RV camping areas, whether equipped with services or not, and the presence of site management and/or facilities for camping purposes. Ski resorts, often nestled within mountainous regions, serve as recreational destinations that cater to winter sports enthusiasts. These establishments provide The rights-of-way associated with ski trails, which are carefully managed areas on the hills, as well as the service facilities such as ski lifts and visitor centers, play a crucial role in the ecological dynamics of the surrounding environment. These designated pathways not only provide access for skiers and visitors but also have significant implications for the local flora and fauna. The ski trails' rights-of-way, meticulously planned and maintained, serve as corridors that traverse through various ecosystems. These pathways can intersect with natural habitats, impacting the movement and behavior of wildlife species. It is essential to consider the potential Recreational trails, also known as nature trails or hiking trails, are pathways designed for outdoor enthusiasts to explore and engage with the establishment of pathways within natural reserves or non-urban landscapes to facilitate pedestrian movement and provide opportunities for leisure and outdoor activities. The establishment and preservation of pathways within recreational parks and private properties are integral components of environmental stewardship in the realm of outdoor recreation and omits engagements that pertain to the utilization of the pathway, such as the act of traversing it on foot (Wong, 2004).

1.5 Docks and marinas: These are infrastructures that have a significant impact on the environment due to their association with recreational boating activities. To be discerned from the recreational boating endeavor, the scope of this phenomenon encompasses the practice of local dredging. Examples of anthropogenic structures commonly found in aquatic environments include docks, marinas, and boat launches.

2. Agriculture and aquaculture: Agriculture's growth and intensification during the 20th century enhanced food security and reduced poverty, but these gains came at the expense of the environment (Tilman 1999). The ecosystem services that nature provides to man have been lost or deteriorated, and natural ecosystems have been destroyed (MEA 2005). It should come as no surprise that these environmental changes have also resulted in local biodiversity losses and a higher global risk of extinction. IUCN data show that one of the main contributors to global endangerment is agriculture. Therefore, through the 21st century, agriculture will continue to have a negative impact on ecosystems and the biodiversity that goes along with them. This includes threats from agricultural activities like the expansion and intensification of agriculture and livestock farming, including silviculture, mariculture, and aquaculture, as well as related infrastructures. This includes the initial alteration of habitat (deforestation, filling/excavation, draining of wetlands, etc.) related to cultivation or infrastructure development, as well as uses and practices (intensification of agricultural practices, use of machinery, etc.), but excludes the transportation of the produced resources, crop irrigation, and pollution.production of annual and perennial non-timber crops, both annual and Farms, crop fields, vineyards, mixed agroforestry systems, and other non-timber crops grown for food, fuel, or other purposes at the cost of land degradation and habitat loss of several species. Some specialty cultures in combination are categorized into a general threat category due to the diversity of agricultural techniques and their associated effects. Wide-row crops, such as maize (corn), soybeans, barley, vegetable crops, oats, wheat, canola, and hemp, need the most intensive farming techniques and have the greatest consequences. Annual cropping systems also contain these crops. However, compared to annual crops, perennial crops are connected to less intensive farming methods that have a smaller negative ecological impact. For example, hay, alfalfa, clover, pastures, and fodder crops. Different forms of agriculture specialty crops, the ecological effects of which can vary according to the methods employed. For instance, vineyards, berry fields, sod farms, and cranberry bogs. A significant amount of forest cover is covered year-round by wood plantations used to generate timber, fiber, or other non-timber products. This kind of plantation is frequently made up of non-native tree species and is typically found outside of natural forests. For the manufacturing of pulp, hybrid poplars and other types of plantation wood are employed. Plantation-produced non-timber goods cultivation of trees for the production of fruits, nuts, bark, or sap outside of natural forests, such as in orchards, walnut plantations, or rubber plantations.

3. Energy production & mining: Energy production and mining are two significant activities that have a profound impact on the environment. These processes involve the extraction and utilization of natural resources, often leading to various environmental consequences. The extraction of fossil fuels, such as ecological risks stemming from the extraction and utilization of non-biological resources are multifaceted. These risks encompass the alteration of the natural habitat due to land conversion, the establishment of essential infrastructure, and various activities associated with resource exploitation such as mechanized operations, exploration, excavation, drilling, and the storage of ore or drill cuttings. Additionally, the presence of tailings ponds, settling ponds, and the subsequent reclamation of the site after development further contribute to these risks. It is important to note that this analysis excludes the potential impacts on wildlife resulting from transportation of resources and the release of contaminants, as well as the occurrence of wildlife collisions with the infrastructure associated with resource extraction and development (Sonter *et al.,* 2020).

3.1. Oil & gas drilling/exploring: Oil and gas drilling is a process that involves the extraction of fossil fuels from beneath the Earth's surface. This activity has significant environmental implications and is of particular interest to environmental biologists like engagement in the exploration, prospecting, development, and production of petroleum or other hydrocarbons within the realm of onshore and offshore oil and natural gas operations, particularly in freshwater environments resulting in loss of biodiversity due to habitat displacement, forest fragmentation and deforestation, and escalated exploitation of several species (Cucco *et al.,* 2023; Agbagwa and Ndukwu, 2014).

3.2 Mining & quarrying: Mining activities have the potential to exert direct impacts on the environment through the release of chemical substances and physical agents. Chemical emissions, such as mercury or cyanide used in gold extraction, as well as the release of acids from oxidised minerals when certain ores are exposed to air, contribute to the chemical pollution associated with mining. Additionally, physical agents like dusts and aerosols generated during mining operations can also have detrimental effects. Furthermore, mining activities can indirectly affect biodiversity through the development of associated infrastructure. The establishment of mining-related infrastructure often attracts human populations, which can lead to new threats or worsen existing ones, such as over-exploitation of natural resources. These indirect impacts can extend beyond the immediate vicinity of mining sites, potentially affecting biodiversity over large distances. In summary, mining activities have the capacity to directly and indirectly impact biodiversity across landscapes and regions, resulting in negative consequences for biodiversity on a significant scale (Sonter *et al.,* 2018). Minining activites also includes the scientific investigation and assessment of natural resources for the purpose of extracting and utilizing minerals, rocks, and other substrates such as sand and gravel. This includes activities related to the treatment of waste materials, such as settling and tailings ponds, as well as the expansion and restoration of mining sites after their development. The scope of this threat does not encompass the intricate dynamics of resource transportation and the detrimental effects of acid mine drainage. While peat harvesting may not fall under the category of mineral resources, it is important to acknowledge that this practice can have significant ecological implications, akin to those observed in quarries and sandpits. This is primarily due to the utilization of similar excavation machinery, which can result in comparable environmental impacts. Instances of anthropogenic activities that have been observed to significantly impact the environment include the extraction of coal from mines, the mining of diverse metallic resources such as gold, copper, nickel, and magnesium, as well as the operation of quarries and sand pits. Subterranean mining operations, surface excavation sites, quarrying and sand extraction facilities, as well as peat extraction activities (Giam *et al.*, 2018).

3.3. Renewable energy sources: These are a crucial aspect of sustainable development and environmental conservation such as solar, wind, hydro, and geothermal power. The investigation and advancement of ecological infrastructure and the generation of sustainable energy, with the exception of its transportation, are the focal points of interest. Hydroelectric dams, wind farms, hydrokinetic turbines, and solar farms are a few illustrative instances of sustainable energy infrastructure.

4. Transportation & service corridors: Transportation and service corridors pose significant threats to the environment due to the extensive development, utilization, and upkeep associated with these infrastructures. These corridors, including roads, pipelines, power lines, and other similar structures, along with their accompanying rights-of-way, have the potential to cause detrimental impacts on the surrounding ecosystems. These particular facilities have the potential to introduce barriers or impede the natural mobility of species, while also generating disruptions during maintenance activities (e.g., disturbance of falcon nests during bridge maintenance; widespread avoidance of roads by caribou, etc.). This ecological concern also encompasses the management of vegetation within rights-of-way maintenance activities and the potential impacts on wildlife due to collisions.

4.1. Roads, railroads, logging roads and network bridges: The impact of roads, railroads, logging roads, and network bridges on the environment: The processes involved in the establishment, upkeep, and existence of the surface transportation network. The ecological ramifications of rights-of-way can exhibit variability contingent upon their dimensions. Bridges Encompasses transportation infrastructure, specifically road and rail network bridges. The utility and service lines refer to the network of infrastructure that provides essential services to communities. These lines encompass various systems, such as water supply, sewage, electricity, gas, telecommunications, Linear networks play a crucial role in the efficient transportation of energy and diverse resources, encompassing their associated rights-of-way. Potential impacts: The presence of man-made electrical infrastructure may result in the unfortunate occurrence of electrocution, which can have detrimental effects on the local wildlife populations. Additionally, these structures can act as barriers, impeding the natural dispersal patterns of various species. Furthermore, the construction and maintenance of such infrastructure can lead to modifications or even complete loss of habitats, further Power and service lines, also known as utility lines, are essential infrastructure components that play a crucial role in modern society. These lines are responsible for transmitting electricity, telecommunications, and other vital The interconnected infrastructure comprising buildings, towers, pylons, and poles that facilitate the distribution of electricity and telecommunications, with the exception of hydroelectric dams or power plants. The extent of rights-of-way can exhibit variability based on their dimensions. The transportation infrastructure that facilitates the movement of oil and gas resources, commonly known as oil and gas pipelines, plays a pivotal role in the global energy sector. These pipelines serve as conduits The infrastructure network responsible for the transportation of oil and natural gas products encompasses both aboveground and underground systems, with the exclusion of extraction sites. This intricate network comprises various components, such as seismic lines, which aid in the exploration and mapping of subsurface geological formations. These lines play a crucial role in identifying potential reservoirs and determining the optimal locations for extraction activities. However, it is important to note that the focus of this discussion lies solely on the infrastructure involved in the transportation of these resources, rather than their extraction.

4.2. Shipping lanes: Ecological implications linked to the transportation of individuals and commodities across aquatic environments, encompassing oceans, estuaries, rivers, and other water bodies, alongside the potential impacts stemming from the expansion and alteration of waterways. This classification does not encompass endeavors that pertain to the realm of leisurely navigation on water bodies. The ecological impact of shipping vessels on wildlife is a matter of concern within the field of environmental biology. The collision of ships with wildlife poses a significant threat, leading to detrimental consequences for various species. Additionally, the wake waves generated by these vessels can cause substantial damage to the surrounding ecosystem. Furthermore, the mere presence of ships, as they transport people and goods, can disrupt the delicate balance of the environment, causing disturbances that have far-reaching implications. The aforementioned activity encompasses the process of dredging shipping lanes, which serves to enhance the ease of boat transportation. However, it is important to note that dredging operations are not conducted within marinas and docks that are designated for locks and canals. The intricate network of locks and canals plays a pivotal role in the ecological dynamics of various aquatic ecosystems. These man-made structures, designed to regulate water flow, establishment, ongoing management, and utilization of locks and canals, encompassing the accompanying dredging activities.

4.3. Aerial trajectories: Utilizing the airspace for the purpose of human and material transportation, with the exception of leisurely pursuits such as hang gliding and unmanned aerial vehicles (UAVs). The study of flight paths is a crucial aspect within the realm of environmental biology. Understanding the patterns and trajectories of various flights provides valuable insights into their engaging in aerial activities such as flying airplanes, paragliders, helicopters, or ultra light aircraft at low altitudes has the potential to result in avian collisions or disruption of other wildlife species.

5. Biological resource use: The utilization of biological resources is a significant aspect within the realm of environmental biology which shows the various ways in which living organisms are utilized for human purposes. The ecological perils arise from the utilization and consumption of untamed biological resources encompassing the ramifications of both lawful and illicit harvesting practices, as well as inadvertent exploitation. The categorization of threats with the perturbation and regulation of specific species, encompassing the conversion and deterioration of habitats, the establishment of interconnected infrastructure, and the accompanying activities and methodologies linked to such endeavors (e.g., utilization of machinery, storage of timber, management of soil), with the exception of resource transportation (e.g., construction of logging roads) and the extraction of peat.

5.1. Non-lethal Poaching/persecution and harvesting of terrestrial and aquatic animal and animal products: The illicit activities of poaching, persecution, and harvesting of both terrestrial and aquatic fauna, as well as their derived products, have become pressing concerns in the realm of environmental biology. Engaging in the pursuit of animal species or the acquisition of animal products for various purposes, such as commercial trade, recreational activities, sustenance, cultural practices, research endeavors, or population management, which encompasses hunting of land-dwelling species and trapping of semi-aquatic species. This classification also encompasses unintentional captures, management and persecution, while excluding the extraction of organisms for scientific investigation. The practice of hunting and harvesting wild animal species, either for recreational purposes or as a means of subsistence, is conducted under the guidance of management measures. Incorporates unintentional mortality, yet unauthorized extraction or mortality ought to be categorized as "Poaching/Persecution of terrestrial organisms," with the exception of the pollution of ecosystems caused by the presence of solid lead resulting from the utilization of hunting ammunition. This encompasses the act of hunting using firearms, bows or crossbows, or blunt instruments for recreational or sustenance purposes, as well as taxidermy and the collection of trophies. The practice of capturing and procuring wild terrestrial or semi-aquatic animal species, such as beavers, through the utilization of trapping techniques, which are regulated by a set of management measures. The inadvertent loss of life, albeit regrettable, is an inherent aspect of animal control through trapping, which falls within the purview of "Terrestrial Animal Management/Control." The capture of untamed terrestrial or semi-aquatic organisms for the purpose of obtaining their fur, meat, preserving their bodies through taxidermy, acquiring trophies, or unintentionally ensnaring non-target avian predators. The sustainable extraction of terrestrial animal resources through non-lethal means, guided by effective management strategies like the practice of collecting feathers from birds' nests on the ground, or the process of gathering droppings from various avian species, commonly known as guano collection are some of the non-invaisve methods of collection. Extraction of terrestrial fauna or animal-derived resources (e.g., plumage) for personal, commercial, or retaliatory motives, or any activities is regarded as mistreatment or disturbance of wildlife. For instance, the activities involving the targeted elimination of coyotes or avian predators by hunters, the intentional infliction of harm upon snakes due to human apprehension, the illicit gathering of eggs from seabirds or shorebirds, the unlawful trafficking of wildlife for their hides, flesh, or as commodities in the pet industry. The regulation and oversight of terrestrial fauna involving the intentional removal of individual organisms from a terrestrial species for the benefit of human interests is implemented through a set of management protocols. The practice of cormorant culling, also known as selective population control, is a management strategy employed to address ecological concerns associated with cormor.

5.2. Poaching/eradication and non-lethal harvesting of terrestrial plant and plant products or fungi: Engagement in the collection of terrestrial flora or mycological specimen, procurement of indigenous flora, fungi, or other non-animal/non-timber organisms for various purposes such as commercial trade, recreational activities, sustenance, cultural practices, and ecological management, while explicitly excluding scientific investigation. The act of engaging in recreational or subsistence harvesting of plant or fungi species has been observed to have a significant impact on the survival and well-being of the individual organisms involved. This practice is subject to strict management measures in order to regulate its potential negative consequences. The unauthorized collection of terrestrial plants or fungi, such as the recreational or subsistence harvesting of wild leeks, should be appropriately categorized as "Poaching/Eradication of Terrestrial Flora or Mycota." The practice of commercially harvesting plant or fungi species, which entails a detrimental impact on the individual organisms, is subject to regulatory measures. It is important to note that this excludes activities such as peat harvesting and the utilization of products derived from plantations like commercial harvesting that falls within this context is the extraction of fiddle heads is an illustrative example. These activities involve the careful extraction of resources from the natural environment, specifically targeting cedar bark and sugar maple trees. The intentional act of poaching and exterminating terrestrial flora and fungi, as well as the illicit collection or exploitation of these organisms for personal or economic gain, or their eradication based on biased perceptions towards certain species, exemplified by the unlawful gathering of American ginseng or the elimination of cow parsnip due to its resemblance to the invasive alien species known as giant hogweed, encompasses the inadvertent repercussions on other species, while excluding activities such as cutting or vegetation management carried out for maintenance purposes or during the initial stages of development, such as the removal of dandelions from lawns. The deliberate management and control of terrestrial plant species or fungi involves the strategic intervention aimed at mitigating the negative impacts caused by these organisms, while considering their ecological significance. This entails implementing measures to regulate the population dynamics and distribution of these plants or fungi, with the ultimate goal of minimizing their detrimental effects on the environment and promoting the overall well-being of ecosystems.

5.3. Logging & wood harvesting: Logging and wood harvesting refers to the extraction of trees and other forest species from their natural habitats for the purpose of obtaining timber or fiber, excluding those obtained from plantations. This process involves various activities such as cutting down trees, utilizing machinery, storing wood, and managing debris. However, it does not encompass the transportation of harvested materials or the erosion that may occur during this phase. The complete removal of the forest cover results in the extensive deforestation of the area, leading to the loss of vital ecological habitats and the disruption of various interconnected ecosystems. This significant alteration to the landscape has profound implications for biodiversity, as it can result in the process of selectively removing cuttings from the forest ecosystem results in a significant reduction in the overall forest cover. The practice of clear-cutting and its associated cutting techniques, such as continuous thinning (CT), crown removal (CRS), crown pruning (CPRS), crown pruning with heavy residual stand (CPHRS), and crown pruning with precommercial thinning (CPPTM) are selectively reducing the extent of the forest canopy. The practice of implementing partial cutting techniques in forest management involves selectively removing a specific portion of trees while ensuring that a sufficient amount of forest cover is retained. For instance, the practice of shelter wood cutting and selection cutting can be observed in the realm of environmental biology. Enhanced logging practices in ecologically diverse forest ecosystems. Silvicultural interventions exert a transformative influence on the forest's composition, thereby fostering the proliferation of specific plant species with enhanced growth potential. These interventions have the potential to modify the ecological landscape by influencing the accessibility of sustenance and refuge for wildlife species. For instance, the practice of pre-commercial thinning, which involves selectively removing trees in young stands to enhance their growth and development, and tending felling, which refers to the careful and deliberate cutting of trees to the process of artificial regeneration of forest stands involves the deliberate and controlled establishment of new trees in areas where natural regeneration may be limited or insufficient. This practice is employed by environmental biologists to enhance forest ecosystems and promote their implementation of tree planting initiatives within natural forest ecosystems, as opposed to non-forest areas, serves as a means to facilitate the restoration and rejuvenation of stands comprised of commercially valuable species. This approach is particularly crucial in cases where the natural regeneration of these stands is either absent or inadequate. The strategic handling and manipulation of the surrounding environment and detritus during the process of cutting, as well as in the subsequent stages such as scarification and the creation of windrows using woody debris. The practice of fishing and harvesting aquatic resources is an integral component of our interaction with aquatic ecosystems. It involves the extraction of various species of fish, shellfish, and other aquatic organisms for human consumption and commercial purposes. The extraction of aquatic species, encompassing both flora and fauna, for various purposes such as commercial trade, recreational activities, subsistence livelihoods, cultural practices, scientific research, or even population management and deterrence, is a prevalent practice in our ecological domain. This particular classification also encompasses the unintentional capture of non-target species (known as bycatch), while excluding any activities conducted for research purposes.

5.4 Poaching/eradication and non-lethal harvesting of aquatic organisms: The extraction of aquatic species such as overfishing activities for recreational or subsistence purposes, subject to regulations and management strategies. The illicit extraction of aquatic resources through fishing activities ought to be categorized within the domain of "Poaching/persecution of aquatic species" which incorporates incidental catch and potential harm to released organisms, while omitting the ecological repercussions stemming from the deposition of solid lead originating from fishing equipment within habitats like the engagement in recreational angling activities targeting sturgeon, the inadvertent capture of mudpuppies during ice fishing endeavors, the unfortunate occurrence of turtles inadvertently ingesting fishing hooks, and the responsible acquisition of authorized species for personal fish-keeping purposes. The practice of engaging in commercial fishing and the extraction of aquatic species for commercial utilization is subject to regulatory measures aimed at managing its impact on the environment, with a primary focus on the species affected rather than the potential habitat damage caused by sea bottom trawling. Incorporation of incidental catch, while excluding the detrimental impact of abandoned fishing gear on biodiversity, such as the entanglement of wildlife. For instance, this encompasses the utilization of nets and fishing equipment in commercial fisheries, specifically for eel harvesting, as well as the involvement of factory ships. Additionally, it acknowledges the inadvertent capture of marine mammals within the expansive nets employed in industrial fishing operations. The intentional and unlawful extraction of aquatic organisms for personal or economic gain, or the act of targeting, disturbing, mistreating, or inflicting intentional harm on them due to biased attitudes towards the species, such as the illicit capture of glass eels. The regulation and manipulation of aquatic species through targeted elimination of individuals for the purpose of human benefit is a practice guided by management strategies. Examples of such practices include the utilization of lampricides to control lampreys, the application of BTi to manage mosquitoes during their aquatic larval stage, and the implementation of water weed cutting techniques.

6. Human intrusions & disturbance: Threats from human activities (unrelated to the use of biological resources) that disturbs, alter or destroy habitats and their species. Recreational activities with generally low ecological impact that are conducted in natural areas for recreational purposes away from road networks to be distinguished from threat (tourism and recreation areas with a significant footprint), which is a source of pressure primarily on habitats, whereas recreational activities have a more direct impact on individuals of species (disturbance, mortality) and, to a lesser extent, habitats. Using recreational motor vehicles like ATVs, motocross motorcycles, snowmobiles and hiking, walking, cycling or horseback riding on or off trails in natural environments including opportunistic observation of nature, but excludes disturbance by intensive observation/photography that is oriented towards one of several target species for example, walking, jogging, running, dirt biking, geocaching, orienteering, disturbance from users or their domestic animals. Recreational use of cliffs and rock faces, recreational boating, wilderness camping E.g., rock climbing, hang-gliding, use of drones and Caving and use of recreational boats and watercraft that disturb wildlife, incur collisions with animals, and induce wake damage for example, yacht, zodiac boats, watercraft. Wilderness camping without amenities away from dedicated networks and wildlife observation/photography or special events in natural environment without any gathering disturbs the target species due to harassment or through the use of attractants and lures photographers attracting birds of prey with domestic rodents. Outdoor performances in natural settings, gatherings that cause trampling and disturbance of habitat for example, outdoor concerts, gatherings on beaches that incur some trampling, outdoor sports competitions in natural habitats. Riots, War, civil unrest and military and paramilitary activities without any permanent ecological footprint that are to be distinguished from the construction and use of permanent military bases such as military intervention in conflicts, transportation using military vehicles, minefields. Military exercises and Off-base military training activities with a local footprint for example, unexploded ordnance, trampling from military training activities, firing ranges, military equipment testing. Work & other activities carried out in natural areas (undeveloped areas) for purposes such as research activities that are governed by management measures can affect species by causing a disturbance, by collecting individuals, or by degrading the environment like Research fisheries requiring mortality, trampling by research teams.

7. Natural system modifications: Threats from activities that are generally carried out to improve human welfare, but may result in habitat degradation or destruction including the development or redevelopment (management) of natural and semi-natural habitats, as well as certain natural processes that can act as threats. Some examples are mentioned below:

7.1 Fire & fire suppression: Suppression or increase in fire frequency, severity or scope, changes in the natural fire regime that are directly related to human activity for example, out of control agricultural burning, campfires. Interventions related to suppression in the fire regime are aimed at preventing and putting out forest fires (fire management) like putting out forest fires, controlled burning, creating firebreaks and trenches, and other measures.

7.2 Dams & water management/use Facilities or activities: Water level management using dam construction, operation and water management using non-power dams alter the natural water regime (flow or water levels) and dismantling of dam results in habitat loss by drying out the beaver-created basin and flooding lands downstream. It could also potentially cause loss of accumulated sediments due to increased flow in streams farther downstream and development of infrastructure that promotes the free flow of water (installation of drains), decision to maintain dams, the designing, installation and management of Water using culverts that are used to permit water flow under roads or railroads can cause discontinuities in streams and promote erosion.

7.3 Drainage in agricultural and forest environments: Construction and maintenance of channels that drain surface waters in agricultural and forest environments for example, draining private wood lots to increase maple or timber production in forested environments**. 7.4 Withdrawal of surface and ground water:** Withdrawal of fresh surface water for human consumption, crop production or other purposes for example withdrawal by municipalities, spring water bottling companies and farmers; reservoirs for firefighting, creation of man-made lakes, pumping water from the water table.

8. Native, Invasive & other problematic species, genes & diseases: Threats posed by non-native and native species (plants, animals, pathogens or genetic materials) that have or are expected to have harmful effects on biodiversity following their introduction, spread or increase in population (abundance). Invasive non-native/alien plants & animals were not originally present within an ecosystem, but were directly or indirectly introduced into or spread in the ecosystem as a result of human activities. The concept of exotic species includes species that are not native to a specific habitat; it can therefore include the introduction of species that are considered native to a different region of Quebec (e.g., American mink invasion of the Magdalen Islands). Domestic species are also considered nonnative, whether they are feral or semi-domesticated (e.g., domestic cats going outside). Also includes introduction of wildlife due to "mercy releases". Problematic native plants & animals that were originally present in ecosystem(s), but whose populations have increased to a level where they are now "out of control" or overabundant as a direct or indirect result of certain human activities. Habitat alteration by beavers cause flooding/drainage of habitats, increased grazing by vertebrates like white-tailed deer and snow geese and localized increase in invertebrate grazing like increased grazing of American ginseng by native slugs, Insect pest epidemics causing increases in insect pest density, eastern spruce budworm outbreaks, increased predation by mesopredators such as racoons, striped skunks, foxes, coyotes, increased predation by large predators (large ungulates) due to an increase in wolf density; increased predation by seals, intentional reinforcement of predator populations, ectoparasites like fleas, ticks, mites, Interspecific competition with a favoured species for example, exclusion of Horned Grebe by Pied-billed Grebe through competition for the same niche results in large-scale impacts on the ecosystem.

Introduced genetic material on human modified or altered organisms/genes like E.g., pesticide-resistant cereals/forages, use of genetically modified insects for biocontrol, genetic material from silviculture like genetically modified trees, and genetic material from aquaculture genetically modified salmon pose a great threat to biodiversity in natural environments by competing with wild populations or hybridizing with them and altering their gene pool like genetic material from agriculture.

Pathogenic diseases caused by various taxa of pathogenic micro-organisms like bacterial, fungal and viral pathogens living within hosts such as ranavirus in amphibians, rabies in raccoons, white-nose syndrome in bats (WNS), snake fungal disease (SFD), salamander chytrid disease (Bsal), fungal pathogens affecting the roots of American ginseng, worm-induced disease that is directly induced by a worm (helminthiases) for example, flatworms, nematodes, nemertean worms and protozoan-induced diseases, prion diseases, chronic wasting disease of cervids (CWD) are causing disease outbreaks causing great mortality and reduction of biodiversity.

9. Pollution: Threats that is associated with the introduction of foreign or excess material/energy from point and non-point sources. Threats that are posed by pollution are typically correlated with other human activities listed in the other sections (e.g., air pollution from cars, water pollution from sewage, agricultural effluents). Although there is a direct correlation between pollution and these other threats, their impact (scope and severity) is often evaluated separately from the source activity.

9.1 Domestic & urban waste water: Domestic wastewater liquid may be Point or non-point source wastewater and domestic waste from residential and urban areas that is produced by urban centers and discharged primarily by the sewage system for example, runoff effluents resulting from urban activities that are separate from the water supply system, oils and other hydrocarbons discharges from municipal waste treatment plants, leaks from sewers/septic tanks, untreated discharges, pit toilets, medical components in water (birth control hormones, antidepressants, antibiotics), toxoplasmosis, etc.

9.2 Industrial & military effluents Wastewater: Pollutants and effluents from industrial and military sectors, including mines, energy production sectors and other resource extraction industries may contain various nutrients, sediments, toxic substances and chemicals, among others result from deliberate or accidental spills that are legal or illegal, are responsible for environmental damage. Oil spills from vehicle fuel tanks or from facilities that are associated with hydrocarbon extraction and transportation like oil spills from grounded vessels, military vehicles, pipeline failures. Acid mine drainage (AMD), Flame retardant, PCB, mercury and Industrial lead released into the environment by industrial effluents and other industrial discharges, unidentified or mixed toxic liquid chemicals that are released from industrial plants are few more examples where intoxication due to natural sources of these contaminants is likely to result from an indirect threat increasing exposure, for which conservation actions are needed.

9.3 Agricultural & forestry effluents wastewater: Pollutants that are generated by agricultural, silvicultural and aquacultural activities containing various nutrients, toxic substances and chemicals like herbicides & pesticides (insecticides, fungicides etc.) including the use of inputs for controlling crop pests like herbicides are dischargd and transported primarily in drainage systems, runoff and eroded soil causing nutrient loads such as manure, compost, chemical fertilizers as well as soil erosion, sedimentation and sedimentation erosion that are due to agricultural or silvicultural activities, regardless of the presence of local drainage systems (Groh *et al.,* 2022).

9.4 Garbage & solid waste Garbage disposal: solid waste, including materials that can intoxicate or entangle plants and animals (strangulation/asphyxiation from plastic bags, elastic materials, ropes, etc.). Solid lead, asbestos Lead released into the environment in a solid form (e.g., pellets) from a source other than industrial effluents for e.g., lead from ammunition or fishing gear contaminating the environment, ammunitions from shooting ranges and Drifting plastic and entanglement rubbish plastic garbage adrift or ashore of oceans or large water bodies that intoxicate or entangle wildlife such as floating rubbish, nets, robes, buoys, ghost or derelict fishing gear, plastic bags.

9.5 Airborne pollutants: Air contaminant emissions from a point or non-point source, acid rain, smog caused by air pollutant emissions from cars (vehicles in general), ozone atmospheric nitrogen deposition, dust & ashes which are fine particles carried by the wind that pollute the environment when deposited or taken in by organisms E.g., radioactive fallout, wind dispersion of pollutants/sediments, smoke from forest fires or wood burning, excess energy inputs of heat, sound or light that disturb wildlife or ecosystems.

9.6. Light, noise and thermal pollution: Noise from highways, air traffic (airplanes), submarine sonar that disturbs whales and other marine mammals, loud music from outdoor events and engine noise from marine traffic. Light from lamps that attract insects or birds, lights on beaches that disorient turtles, thermal pollution because of heated water discharges from power plants (coal, gas, nuclear, etc.) and atmospheric radiation resulting from ozone layer thinning is also a threat to environment.

10. Geological events: Threats from catastrophic geological events such as volcanic activities, eruptions, emissions of volcanic gases, earthquakes, avalanches, landslide, mudslides and associated events (tsunamis, etc.) that directly and indirectly harm the biodiversity by direct mortality and complete habitat destruction of species.

11. Climate change & severe weather Threats: Threats which may or may not be related to climate change and severe climate/weather events outside of the natural range of variation causing major changes in ecosystems that could harm species or habitats of an ecosystem resulting in changes to vegetation communities so to be distinguished from natural vegetation succession, which may threaten open-country species for example, migration of deciduous trees towards the boreal forest, rising sea levels, desertification, thawing permafrost (in tundra), coral bleaching (Omann *et al.,* 2009). Phenological mismatch behaviors have evolved in several species to adapt to seasonal changes become unsynchronized due to irregularities or delays in the cycle of the seasons. E.g., torpor in hibernating animals that is initiated before the season gets cold. Changes in geochemical regime and large-scale changes in an ecosystem's physico-chemical makeup such as changes in pH of habitats, ocean acidification, changes in salinity, changes in temperature regimes periods in which temperatures of the air, water or soil either exceed or fall below the normal range of variation, gradual temperature change which altered sex-ratio in several species relying upon a temperature dependent sex determination, reduction of dissolved oxygen that is available to fish species, earlier ice-free dates, thawing of permafrost affecting bird breeding sites. Increase in temperature fluctuations disturbs the phenological responses of wildlife as the rise in the frequency of freeze-thaw events, rain-on-snow events, etc., changes in precipitation & hydrological regimes periods in which the amount and frequency of precipitation either exceeds or falls below the normal range of variation that are associated with storms and heavy weather that may lead to overabundant rains or droughts, increase of fluctuations in the precipitation regime that are related to the precipitation regime, which have impacts on the hydrology of natural habitats and storms & severe weather events as a major change/shift in the storm season such as thunderstorms, tropical storms, hurricanes, cyclones, tornadoes, hailstorms, ice storms, blizzards, dust storms, storm surge, erosion of shorelines/beaches during storms and Heat waves or Extreme cold spells.

12. Other ecosystem modifications: Other activities that contribute to habitat alteration or loss by redeveloping natural systems to improve human welfare like shoreline alteration E.g., shoreline hardening, riprap along shorelines, breakwaters, concrete walls, shoreline filling. Natural vegetation succession, erosion and sedimentation causing habitat loss for species of early successional habitats and transport and deposition of sediments that is caused by natural erosional processes such as beach development including creation of beaches, their nourishment (substrate replenishment) and maintenance, removal of snags in watercourses and other structures that are used by wildlife within watercourses to promote water flow, embellish the landscape, or facilitate boating. Sea bottom trawling also alters marine habitats.

References:

1. Agbagwa, I. O. & Ndukwu, B. C. (2014). Oil and gas pipeline construction-induced forest fragmentation and biodiversity loss in the Niger Delta, Nigeria. *Natural Resources*, *5*(12), 698.
2. Cardoso, P., Amponsah-Mensah, K., Barreiros, J. P., Bouhuys, J., Cheung, H., Davies, A. & Fukushima, C. S. (2021). Scientists' warning to humanity on illegal or unsustainable wildlife trade. *Biological Conservation*, *263*, 109341.
3. Critchlow, R., Plumptre, A. J., Driciru, M., Rwetsiba, A., Stokes, E. J., Tumwesigye, C. & Beale, C. M. (2015). Spatiotemporal trends of illegal activities from ranger-collected data in a Ugandan national park. *Conservation biology*, *29*(5), 1458-1470.
4. Cucco, A., Rindi, L., Benedetti-Cecchi, L., Quattrocchi, G., Ribotti, A., Ravaglioli, C. & Brandini, C. (2023). Assessing the risk of oil spill impacts and potential biodiversity loss for coastal marine environment at the turn of the COVID-19 pandemic event. *Science of The Total Environment*, 164972.

5. Giam, X., Olden, J. D. & Simberloff, D. (2018). Impact of coal mining on stream biodiversity in the US and its regulatory implications. *Nature Sustainability*, *1*(4), 176-183.
6. Gomez, L. (2021). The illegal hunting and exploitation of porcupines for meat and medicine in Indonesia. *Nature Conservation*, *43*, 109-122.
7. Groh, K., Vom Berg, C., Schirmer, K., & Tlili, A. (2022). Anthropogenic chemicals as underestimated drivers of biodiversity loss: scientific and societal implications. *Environmental Science & Technology*, *56*(2), 707-710.
8. Mohan, S., & Joseph, C. P. (2021). Potential hazards due to municipal solid waste open dumping in India. *Journal of the Indian Institute of Science*, *101*(4), 523-536.
9. Omann, I., Stocker, A., & Jäger, J. (2009). Climate change as a threat to biodiversity: An application of the DPSIR approach. *Ecological Economics*, *69*(1), 24-31.
10. Prakash, S., and Verma, A. K. (2022). Anthropogenic activities and Biodiversity threats. *International Journal of Biological Innovations*, *4*(1), 94-103.
11. Sonter, L. J., Ali, S. H., & Watson, J. E. (2018). Mining and biodiversity: key issues and research needs in conservation science. *Proceedings of the Royal Society B*, *285*(1892), 20181926.
12. Sonter, L. J., Dade, M. C., Watson, J. E., & Valenta, R. K. (2020). Renewable energy production will exacerbate mining threats to biodiversity. *Nature communications*, *11*(1), 4174.
13. Theodorou, P. (2022). The effects of urbanisation on ecological interactions. *Current Opinion in Insect Science*, *52*, 100922.
14. Veach, V., Moilanen, A., & Di Minin, E. (2017). Threats from urban expansion, agricultural transformation and forest loss on global conservation priority areas. *PLoS One*, *12*(11), e0188397.
15. Wong, P. P. (2004). Environmental impacts of tourism. *A companion to tourism*, 450-461.

EFFECT OF HEAT STRESS IN HORTICULTURAL FRUIT CROPS

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Introduction:

Unfavorable natural condition and extremes temperature are imperative abiotic stresses causing serious yield misfortune in natural product crops. Natural stresses are the essential cause of sleek misfortunes around the world, decreasing normal step down for the major crops by more than 50 per cent. Warm push is anticipated to change to be a major issue in diminishing sleek generation in upcoming a long time due to worldwide warming (Wahid *et al*., 2007). Heat Stress caused by short-term and permanent increases temperature causes a significant decrease in yield, crop quality is improving in many parts of the world. High temperatures encountered at different stages of crop growth and development influences various physiological processes. Heat stress is generally considered to be an increase in temperature of 10 to 15°C normal for long enough at room temperature causes irreparable damage to all aspects of plant growth and development. Heat Stress disrupts basic biochemical reactions, normal functioning of cells, which mainly affects photosynthetic roles of higher plants (Weiss and Berries, 1988). Reproductive processes are also greatly affected by heat stress in most of plants. High temperature causes an organization of morphological, anatomically and physiological and biochemical changes in the plants which affect growth and development and may lead to the drastic reduction of economic yield. Heat stress may cause either direct or indirect injury to plants. Direct injury includes aggregation and denaturation proteins and fluidity of membrane lipids whereas, enzymes inactivation in chloroplast and mitochondria; Inhibition of protein synthesis and degradation and loss of membrane integrity results in cell injury or even death which ultimately leads to catastrophic collapse of cellular organization are included in indirect injury. Further, morphological effects of heat stress include damages like leaves and twig burning, scorching, sunburns in leaves, branches and stems, leaf senescence and abscission, shoot and root growth inhibition, bark cracking, delay flowering/fruiting, poor fruit setting due to sterility, fruit drop and fruit discoloration and quality (Almeida and Valle, 2007). However, physiological distresses in plants causes by high temperature primary effects heat injury on enzymes inactivation, inhibition of protein synthesis and degradation, loss of membrane integrity, increased fluidity of membrane lipids, direct injuries include protein degradation. The secondary effects of heat injury are osmotic stress, oxidative stress, protein denaturation and aggregation, increased fluidity of membrane lipids, inhibition of photosynthesis and respiration.

Mechanism for high temperature tolerance

The fruit plants have inherent ability to survive high temperature and the ability to acquired thermo tolerance. The morphological or anatomical adaptation and the synthesis of unique protein classes such as Heat Shocks Proteins (HSPs) facilitate thermos-tolerance. Enhancing thermos-tolerance can be achieved through the accumulation of various compounds of low molecular mass known as thermo protectants as well as phyto-hormones. Exogenous application of these molecules has helped the plants growing under heat stress. Alternatively, transgenic plants over expressing the enzymes catalyzing the synthesis of these molecules may be raised to increase their endogenous levels to improve heat tolerance. Proline (Pro), glycine betaine (GB) and trehalose (Tre) are just few of the thermos-protectants that plants accumulate in response to stresses. Several other phytohormones including ethylene, brassinosteroids, polyamines, salicylic acid (SA), abscisic acid (ABA), and ethylene as well as potential signaling element like nitric oxide also induce heat tolerance. Under the heat stress the amount of ABA increased which promotes thermos-tolerance by up or down regulating different genes. HSPs are produced at higher rate due to the increase in ABA. Most stresses cause the synthesis of a class of proteins known as heat shock proteins (HSPs). There proteins are grouped into different molecular weight: HSP 100, HSP 90, HSP 70, HSP60 small heat shock protein (SHSPs) and ubiquitin's. HSPs functions as molecular chaperones that controlling the folding, accumulation and removal of damaged proteins. The heat shock response is characterized by a transient alteration of gene expression (synthesis of heat proteins: HSPs) and the acquisition of a higher level of stress tolerance (acclimation). The expression of HSPs positively correlates with acquisition of thermos-tolerance and over expression of HSPs often results in enhanced thermos-tolerance and ultimately improves physiological parameters such as photosynthesis, assimilate partitioning, along with water and nutrient efficiency of the plants. Many proteins are prevented from denaturing at high temperature by HSPs binding to a specific polypeptide within the sub-cellular compartment.

Morphological adaptation of heat and drought tolerance mechanism include water binding (Cactus pear and Fig), presence of thorn (Ker and Ber), deep root system (Aonla and Ber), leaf shedding (Aonla, Ber), reduce leaf area (Aonla, Tamarind, Ker), leaf epicular waxes, leaf latex, leaf orientation (vertical orientation, rolling their leaves along the axis) and so on. These mechanisms maximize conductive or convective loss of heat. Whereas, anatomical adaptation included sunken stomata (Ber, Ker, Cactus pear), thick cuticle (Fig, Cactus pear), wax coating (Ker, Lasora and Fig) and pubescence (Ber, Phalsa and Tamarind) (Pareek and Sharma, 1991).

Effect of high temperature on growth stages of temperate region fruit crops

A. **Apple:** Apple with high temperature exhibit a detrimental chilling effect. Over the past 30 to 40 years apple flavor and texture have evolved in response to climate change. Higher temperature was found to cause a decrease in acid concentration, fruit firmness and water core development irrespective of the maturity index. All the changes have resulted from earlier blooming and higher temperatures during the maturation period (Sugiura *et al.*, 2013). Compared to cool night fruit, warm night fruits skin was less red. Apple cv. Cox and Queen Cox were covered in polythene which reduced the number of fruits by approximately 35 per cent and 41 per cent respectively and increased the temperature of fruit trees relative to the outside trees (Atkinson *et al.*, 1998). Whereas, Li *et al.*, 2004 stated that Starkrimson Delicious apple showed a slower rate of anthocyanin biosynthesis in response to warm weather (mean temperature 25^0c). Water core disorder is brought on by summer temperature above 30^0c (Yamada *et al.*, 2004). In contrast to the susceptible cv. Orin which had higher levels of sorbitol in the cytoplasm and tonoplast, the resistant cv. Fuji displayed a difference in sugar compartmentation and higher levels of fructose and glucose in the vacuoles (Yamada *et al.*, 2005). High temperature leads to fruit splitting in Fuji and bitter pit in Jonagold cultivars of apple.
B. **Apricot:** According to Rodrigo and Herrero (2002) the high temperature caused a reduction in pistil size which in turn caused an abnormal flower and in turn a reduced fruit set.
C. **Grapes:** Sharma *et al.* (2013) found that Thompson seedless cv. on dogridge rootstock experience delayed bud sprouting due to high temperature after foundation pruning. Grapes fruit set was inhibited by temperature above 35^0c (Fischer and Orduz-Rodriguez, 2012). Pollen tube development and ovule viability are the two factors that contribute to the decreased fruit set. In addition to changing fruit quality the high temperature cause earlier grapes harvests. Fruit exposed to high temperature have lower acidity, higher sugars content and alter aroma compounds. Wine color and aroma may be impacted by the intense heat (Mira de Orduna, 2010). According to Coombe *et al.*, (1988) the grapes soluble solids content rose as the temperature rose from 15 to 30^0c. High day temperature or exposure to sunlight during berry development result into berry discoloration thus affecting the market acceptability. High diurnal variation has found to increase the incidence of pink berry disease in Thompson Seedless and its mutant.
D. **Japanese pear**: Excessive heat during initial stage of fruit development cause water core disease (Sakuma *et al.*, 1993).
E. **Kiwi fruit**: According to Hopkirk *et al.* (1989) fruit grown between mid-March and mid-May at temperature 3-4^0c higher than the ambient air temperature had higher starch contents in both the cortex and core tissue, more firmness and lower soluble solids.

F. **Peach**: High temperature causes the shortening of earlier phases of fruit development and decrease fruit size and yield (Stockle *et al.*, 2009).

G. **Raspberry:** Temperature effect the rate of flowering in raspberry cultivar Autumn Bliss. Further, the sensation growth of plant delayed above 24°C thereby affecting flowering in primocane raspberry cultivar (Carew *et al.*, 2000).

H. **Strawberry:** Warm weather develops albinism in strawberry. Fruits suffering from this disorder appear blotted and develop pink or white area on their surface with pale pulp (Sharma *et al.*, 2003).

I. **Sweet cherry:** High temperature (≥ 35°C) at flower developing stage cause abnormal pistil development in Sweet cherry (Beppu *et al.*, 2001).

Effect of high temperature on growth stages of tropical and sub-tropical region fruit crops

A. **Annona:** The air temperature more than 40°C can lead to no fruit setting in Annona spp. (Rao, 2016). Further, the warm temperature governs the production of low viability pollen and hence, asymmetrical and small fruits having few seeds (Higuchi *et al.*, 1998).

B. **Avocado:** Crops can be harmed by heat stress caused by extreme temperature. High temperature can cause sunburn damage to fruit as well as inhibit photosynthetic activity which has an impact on productivity (Anonymous, 2017).

C. **Banana:** Banana plant can relatively persist under prolonged water stress but the combined effects of deficit soil moisture along with prolonged prevalence of temperatures beyond 35°C can reduce banana production (Thornton and Cramer, 2012). The leaf production and relative leaf area growth was affected beyond 33.5°C (Turner and Lahav, 1983). Higher temperature (31-32°C) shortening the bunch development period by increases the rate of plant maturity in Banana (Turner *et al.*, 2007). The high temperatures affect banana growth and production. The Cavendish banana fruit exposed at high temperature greater than 24°C got fruit remained green owing to retention of chlorophyll and associated thylakoid lamellae (Blackbourn *et al.*, 1989). The physiological disorder of sunburn and choking of bunching are associated with high air temperature (>38°C) in banana (Stover and Simmonds, 1987).

D. **Citrus:** The reduction in fruit size, sugars and acid content was reported by Hutton and Landsberg (2000) at air temperature 35°C. Levitt (1980) reported that the sour orange plants were killed when plants exposed to 50.5°C for 15-30 minutes. Sunburn in fruits can be attributed to heat/light stress. The temperature (35/28°C) for two weeks affecting seedling growth with short nodes and small leaves in sour Orange, troyer citrange and valencia oranges (Ahrens and Ingram, 1988).

E. **Golden berry:** Flowering was inhabited in golden berry (Cape gooseberry) when air temperature was higher than 30°C (Fischer and Orduz Rodriguez, 2012).

F. **Guava:** In north India during summer month when there was high temperature and low humidity highly poor fruit set occurs in guava (Chadha and Pandey, 1986).

G. **Litchi:** The heat injury in litchi fruits and mostly occurs on the exposed fruit on south side of the tree. The fruit injured in litchi fruit showed dark blotches on the skin without any damaged to the pulp. Heat injury to the fruits is common where daily air temperature higher than 40°C (Singh *et al.*, 2012). High temperature reduced the both the duration of flushing and interval between flushing. High temperature can cause significant damage to shoot and root growth, sunburn of leaves and maturity of fruits, high temperature also cause leaf abscissions and drying of branches and stems, fruit drop, fruit cracking and sunburn in litchi (Menzel and Waite, 2005).

H. **Mango:** The sudden changes in temperatures due to climate variability would influence not only the vegetative and reproductive cycles but also proportion of female flowers in the panicle, leading to effects on productivity. The pollen viability and fruit set was reduced when mango plant exposed to temperature ≥ 35°C. The panicles emerging late experiencing higher temperatures had higher percentage of hermaphrodite flowers (Ramaswamy and Vijaya Kumar, 1992), signifying that the proportion of male and hermaphrodite flowers change with the prevailing temperatures. Higher temperatures lead to stronger vegetative bias under sufficient nutrient and water availability (Laxman *et al.*, 2016).

I. **Macadamia nut:** The plant produces numerous spindly branches and chlorotic leaves when grown in controlled environment with a constant day temperature of 35°C.

J. **Papaya:** According to Paull and Duarte (2011) the air tendency differs between and within cultivars. The female sterility or non-functional part changes to a functional male part when the temperature rises above 35°C. In bisexual cultivar the degree of sterility rises in direct proportion to temperature.

K. **Pineapple:** According to Paull and Reyes (1996) the temperature increase (max/min 28/18°C) has potential to cause fruit to develop translucency disorder.

L. **Prickly pear:** According to Levitt (1980) when the prickly pear plant was exposed to a temperature higher than 65°C, it dies.

M. **Miscellaneos:** According to Yamada *et al.* (1996) certain species such as cherimoya, coconut, pineapple, soursop and sugar apple can withstand high temperature while others such as Java apple, longan and rose apple are very sensitive to it.

Management practices to alleviate heat stress

A. **Anti-Transpiration:** Anti-transpiration chemical used to minimize the evapo-transpiration rate Application of foliar spray of 3 per cent Kaoline can reduce heat stress by reduce evapotranspiration.

B. **Bark Painting:** Painting or spraying a reflective white coating on exposed trunks and branches can help crack the cambium of dead trees caused by high temperature.

C. **Canopy management:** By selecting certain cultivars, managing fertilizer, pruning and training techniques one can control the amount of fruit shading caused by leaves. Treatments like foliar diseases, leaf stripping, late or excessive pruning and excessive pruning in the summer that diminish canopy cover will all contribute to an increase in sunburn. Controls of sunburn in fruits starts with developing good leaf cover in the canopy to shade the fruit. Fruits most susceptible to sunburn will be those that are most exposed sun then fruit which are not shaded in the afternoon.

D. **Fruit Bagging:** Large percentages of exposed fruits at risk of sunburn can be protected by using shade cloth with 10-30 per cent shade.

E. **Fruit Suppressants/ Film Spray:** Sunburn can be lessened or avoided by using film spray. Surround, Screen Duo and Purshade are example of materials based on Kaoline clay that leave a white particle film on the fruit. Film product like Raynox also shield fruits from sunburn without leaving a white trace (Lal and Sahu, 2017).

F. **Growth regulators:** By applying PGR exogenously plants can be made more resilient to stress. When grapes leaves are under heat stress the application of salicylic acid can sustain increased photosynthesis (Wang, 2010). Crops under stress can benefit from a 100ppm salicylic acid to improve harvest index and stem reserve utilization (Wang *et al.,* 2007).

G. **Irrigation:** In order to prevent heat stress and sunburn irrigation should be applied right before or during heat waves (Lal and Sahu, 2017). The main strategy to lessen heat stress is to use irrigation to meet evapo-transpiration demands. Utilizing misting, sprinkling and overhead watering can also lower the water vapor pressure deficit and lower tissue temperature.

H. **Mulching:** In addition to keeping the canopy cool mulches aid in regulating transpiration. By reflecting light and dissipating radiative heat, the use of low density, organic, reflective mulches like straw will lower surface radiation while holding onto moisture. By lowering total incoming radiation and advected heat, shading cloths are used to partially shade an area.

I. **Nutrient management:** Foliar spray of 0.5 per cent zinc sulphate + 0.3 per cent boric acid + 0.5 per cent + Ferrous sulphate + 1 per cent urea help in minimizing heat stress. During the spray, sufficient moisture should be present in the soil for avoiding leaf scorching. Further, the split application of N and K fertilizers improve plant growth under moderate heat stress. Foliar spray of 2 per cent DAP + 1 per cent KCl (MOP) also used to alleviate heat stress hence, proper plant nutrition is one of the good strategies to alleviate the heat stress (Waraich *et al.,* 2012).

J. **Rootstock:** using tolerant rootstock genotype is one way to enhance fruit trees resistance to heat stress and water shortage. Utilizing heat and drought tolerant rootstocks would help the variety recover more rapidly by reducing the direct effect of the dry weather. Using rootstock for cultivation after becoming more aware of their potential to mitigate the negative effect of heat and drought.

K. **Selection of cultivar:** In temperate fruit crops, the heat tolerance cultivar are Elsanta, KHope and Camarosa in strawberry (Kesici *et al.*, 2013) and BR1 Chimarita, Tropic Beauty and Atens in Peach (Carpenedo *et al.*, 2017). The cultivars for drought and heat tolerance in fruit crop *i.e*. Ruby (Pomegranate), Arka Sahan (Annona), Deanna and Banana-cultivars belonging to BB genome shown to be drought tolerant viz. Karpuravali and Kanthali (Bose and Mitra, 1996).

L. **Selection of fruit crop:** Heat and drought tolerance mechanism include deep root system, leaf shedding, water binding mechanism, presence of thorn, leaf orientation, vertical and rolling of leaves and well-formed canopy. Perennial fruits species with this mechanism should be chosen that are adapted to the high temperatures likely to occur in the specific location. The fruit crops like ber, pomegranate, aonla, fig, ker, tamarind, bordi (*Ziziphus* species), karonda, lasora, khejri and Indian fig can be selected for growing in heat prone area.

Conclusion:

Concern over the high temperature has increased due to the expected increase in frequency and amplitude of this stress in near future. There is urgent need to screen the wild relatives of crops and also other related species as rootstocks for heat tolerance may be intensified because the high temperature stress is the second most important stress after drought that adversely affects on growth, productivity and quality of fruit plants. Efforts should also be intensified to develop heat tolerant varieties by using conventional breeding and biotechnological approaches. To mitigate the adverse impact of heat stress on management practices have been found to be only strategy which can be effectively used to relieve heat stress in fruit crops.

References:

1. Ahrens, M.J., Ingram, D.L. (1988). Heat tolerance of citrus leaves. *Horticultural Science*, 23: 747-48.
2. Almeida, A.A.F.D. and Valle, R.R. (2007). Ecophysiology of the cacao tree. *Brazilian Journal of Plant Physiology*, 19(4): 425-448.
3. Anonymous (2017). Avocado heat damage Follow-up California Avocado Commission, California. Armstrong, W.D., (1980). High temperature-induced chlorosis in Macadamia integrifolia (Doctoral dissertation, University of Queensland).

4. Atkinson, C.J., Taylor, J.M., Lucas, A.S. (1998). Temperature and irrigation effects on the cropping, development and quality of Cox's Orange Pippin and Queen Cox apples. *Scientia Horticulture*, 75: 59-81.
5. Beppu, K., Ikeda, T. and Kataoka, I. (2001). Effect of high temperature exposure time during flower bud formation on the occurrence of double pistils in 'Satohnishiki'sweet cherry. *Scientia Horticulturae*, 87(1-2): 77-84.
6. Blackbourn, H., John, P., Jerger, M. (1989). The effect of high temperature on degreening in ripening bananas. *Acta Horticulture*, 258: 271-78.
7. Carew, J.G., Hadley, P., Darby, J., Battey, N.H. (2000). The effect of temperature on the vegetative growth and flowering of the primocane fruiting raspberry 'Autumn Bliss'. *Journal of Horticulture Science Biotechnology*, 76: 264-70.
8. Carew, J.G., Mahmood, K., Darby, J., Hadley, P. and Battey, N.H. (2003). The effect of temperature, photosynthetic photon flux density and photoperiod on the vegetative growth and flowering of Autumn Bliss' Raspberry. *Journal of the American Society for horticultural science*, 128(3): 291-296.
9. Carpenedo, S., RASEIRA, M., Byrne, D.H. and Franzon, R.C. (2017). The Effect of Heat Stress on the Reproductive Structures of Peach. Embrapa Clima Temperado-Artigo em periódico indexado (ALICE). Chadha, K.L. and Pandey, R.M., (1986). *Psidium guajava* L. *Handbook of flowering*, 5: 43-51.
10. Coombe, B.G. (1987). Influence of temperature on composition and quality of grapes. *Acta Horticulturae*, 206: 23-35.
11. De Orduna, R.M., (2010). Climate change associated effects on grape and wine quality and production. *Food Research International*. 43(7): 1844-1855.
12. Fischer, G. and J.O. Orduz-Rodriguez. (2012). Ecofisiologia en frutales. In: Fischer, G. (*ed*.). Manual para el cultivo de frutales en el trópico. *Produmedios*, 54-72.
13. Higuchi, H., Utsunomiya, N., Tetsuo, S. (1998). High temperature effects on cherimoya fruit set, growth and development under green house conditions. *Scientia Horticulturae*, 77: 23-31.
14. Hopkirk, G. *et al.*, (1989). Effect of increased preharvest temperature on fruit quality of kiwifruit (*Actinidia deliciosa*). *Journal of Horticultural Science*, 64(2): 227-237.
15. Hutton, R.J. and Landsberg, J.J., (2000). Temperature sums experienced before harvest partially determine the post maturation juicing quality of oranges grown in the Murrumbidgee Irrigation Areas (MIA) of New South Wales. *Journal of the Science of Food and Agriculture*, 80(2): 275-283.
16. Kesici, M., Gulen, H., Ergin, S., Turhan, E., Ahmet, I.P.E.K. and Koksal, N. (2013). Heat-stress tolerance of some strawberry (Fragaria× ananassa) cultivars. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 41(1): 244-249.

17. Lal, N. and Sahu, N., (2017). Management strategies of sun burn in fruit Crops-A Review. *International Journal of Current Microbiology and Applied Sciences*, 6(6): 1126-1138.
18. Laxman R.H., Annapoornamma C.J., Biradar G. (2016). Mango. In: Abiotic Stress Physiology of Horticultural Crops. [Rao N., Shivashankara K., Laxman R. (eds)] Springer, New Delhi.
19. Levitt, J., (1980). Responses of Plants to Environmental Stresses (Physiological Ecology): Chilling, freezing and high temperature stresses.
20. Li, X., Hou, J.H., Zhang, G., Liu, R.S., Yang, Y., Lin, J. (2004). Comparision of anthocyanin accumulation and morpho anatomical features in apple skin during color formation at two habitats. *Scientia Horticulturae*, 99: 41-53.
21. Menzel, C.M. and Waite, G.K., (2005). Litchi and longan. Botany, Production and Uses. CAB International, Wallingford, Oxfordshire, UK, .305.
22. Mitra, S.K. and Bose, T.K., (1996). Standardization of propagation techniques by cutting of some tropical fruit crops. *Scientific Horticulturae*, 5: 1-7.
23. Nimbolkar, P.K., Shiva, B. and Rai, A.K., (2016). Rootstock breeding for abiotic stress tolerance in fruit crops. *International Journal of Agriculture, Environment and Biotechnology*, 9(3): 375-380.
24. Pareek, O.P. and Sharma, S., (1991). Fruit trees for arid and semi-arid lands. Indian Farming. 41: 25-33. Paull, R.E. and Duarte, O., (2011). Tropical fruits (Vol. 1). CABI. production. *In: VI International Symposium on Irrigation of Horticultural Crops*, 889: 41-52.
25. Paull, R.E., Reyes, M.E.Q. (1996). Pre-harvest weather conditions and pineapple fruit translucency. *Scientia Horticulturae*, 66: 59-67.
26. Ramaswamy, N. and Kumar, V.M., (1992). Studies of the effects of flowering and fruiting behaviour of south Indian mango cultivate. *In: Fourth International Mango Symposium*.
27. Rao, N. S., Shivashankara, K.S. and Laxman, R.H. eds., (2016). Abiotic Stress Physiology of Horticultural crops.
28. Rodrigo, J. and Herrero, M., (2002). Effects of pre-blossom temperatures on flower development and fruit set in apricot. *Scientia Horticulturae*, 92(2): 125-135.
29. Sakuma, F., Umeya, T., Tahira, K., Katagiri, S. and Hiyama, H., (1995). Effects of high temperature and/or gibberellin treatments during early fruit development on the occurrence of watercore in Japanese pear (*Pyrus pyrifolia* Nakai cv. Hosui). *Journal of the Japanese Society for Horticultural Science*, 64(2): 243-249.
30. Sharma, J., Upadhyay, A.K., Adsule, P.G., Sawant, S.D., Sharma, A.K., Satisha, J., Yadav, D.S. and Ramteke, S.D., (2013). Effect of climate change on grape and its value-added products. *In Climate-Resilient Horticulture: Adaptation and Mitigation Strategies*, 67-80.

31. Singh, G.. Natt, V., Pandey, S.D., Ray, P.K and Singh, H.S. (2012). The Litchi: FAO, New Delhi.
32. Stöckle, C.O., Marsal, J. and Villar, J.M., (2009). November. Impact of climate change on irrigated tree fruit production *Acta Horticulturae*, 889-92.
33. Stover, R.H. and Simmonds, N.W., (1987). Bananas (No. 3rd Ed.). Longman Scientific and Technical. Sugiura, T., Ogawa, H., Fukuda, N. and Moriguchi, T., (2013). Changes in the taste and textural attributes of apples in response to climate change. *Scientific reports*, 3: 1-7.
34. Thornton, P. and Cramer, L., (2012). Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR\u2019s mandate. [Contributing authors include Vladimir Smakhtin of IWMI] (No. H045997).
35. Turner, D.W. and Lahav, E., (1983). The growth of banana plants in relation to temperature. *Functional Plant Biology*, 10(1): 43-53.
36. Turner, D.W., Fortescue, J.A. and Thomas, D.S., (2007). Environmental physiology of the bananas (*Musa* spp.). *Brazilian Journal of Plant Physiology*, 19(4): 463-484.
37. Wahid, A., Gelani, S., Ashraf, M. and Foolad, M.R., (2007). Heat tolerance in plants: an overview. *Environmental and Experimental Botany*, 61(3): 199-223.
38. Wang, Q., Garrity, G.M., Tiedje, J.M. and Cole, J.R., (2007). Naive Bayesian classifier for rapid assignment of rRNA sequences into the new bacterial taxonomy. *Applied Environmental Microbiology*, 73(16): 5261-5267.
39. Waraich, E.A., Ahmad, R., Halim, A. and Aziz, T., (2012). Alleviation of temperature stress by nutrient management in crop plants: a review. *Journal of Soil Science and Plant Nutrition*, 12(2): 221-244.
40. Weis, E.N.G.E.L.B.E.R.T. and Berry, J.A., (1988). Plants and high temperature stress. *In Symposia of the Society for Experimental Biology*, 42: 329-346.
41. Yamada, H., Morita, T. and Amano, S., (2005). Water relations in fruit, leaves and stems of two apple cultivars that differ in susceptibility to watercore. *The Journal of Horticultural Science and Biotechnology*, 80(1): 70-74.
42. Yamada, H., Takechi, K., Hoshi, A. and Amano, S., (2004). Comparison of water relations in watercored and non-watercored apples induced by fruit temperature treatment. *Scientia Horticulturae*, 99(3-4): 309-318.
43. Yamada, M., Hidaka, T. and Fukamachi, H., (1996). Heat tolerance in leaves of tropical fruit crops as measured by chlorophyll fluorescence. *Scientia Horticulturae*, 67(1-2): 39-48.

PEST AND DISEASES OF MANGO IN NORTH INDIA AND ITS MANAGEMENT

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Abstract:

It is one of the important fruit crop cultivated in Bihar and other parts of the country and world. The area of this crop is increasing day by day. The fruit of this tree is consumed in all stages. The raw fruit can be used fresh, preaparing chutneys, squash, Murrabah, powder, pickles, etc. The ripe fruit is rich source of vitamin A. The quality of fruit is affected by different factors such as physiological, mechinal and chemical. The pest and disease incidence in mango orchard one of the limiting factor in expansion of area of mango orchard. It hampers the export. Alphonso is one of the export variety. But it is affected by spongy tissue disoder. Now a days Jardalu is exported from Bihar. So, India have vast scope in extending the area and get ruminarative return from it.

Keywords: Mango, Fruit, Pest, Diseases, Losses, Borer, Anthracnose.

Introduction:

Mango is one of the important fruit crop cultivated in India since thousand years back. Its botanical name is Mangifera indica belonges to family Anacardiaceae. It was originated from Indo-Burma region. India has widest collection of mango varieties around more than 1000(Source:Indian horticulture database). There is also increase in area and production of mango in Bihar. The area increases from 148 thousand hectare to 150. 64 thousand hectare, production from 1272 thousand metric ton to 1479. 58 thousand metric ton and productivity 8. 6 (MT/ha) to 9. 8 (MT/ha) from FY 2014-15 to 2016-17 (Source: Indian horticulture database). Allthough the acerage of mango is good the pest and disease infestation is major limiting factor in getting optimum yield and quality of mango. As per findings of Tandon and Verghese 1985 and Pena et al. 1998 around 400 species of insects and pests infest the mango in different areas in the world. Number of disease also affects the mango plants from nursery stage to post harvest of mango fruits. The major diseases are powdery mildew, die-back, sooty mold, bacterial canker, anthracnose and mango malformation leads to higher damage to the mango crop. The list of mango pests are compiled by De Laroussilhe (1980), Veeresh (1989) and Tandon and Verghese (1985). Due to continious change in climatic condition the emegence of new diseases and pest occure and minor pests and diseases are also serious these days. It have wide range of medicinal properties and nutrional value. The ripe mango fruit is rich source of vitamin A. The raw fruit have diverse use for making powder, chutneys, pickles, squash, etc. The juice of raw mango is used in heat stroke. The bark is used in diphtheria and rheumatism. It is also used as antisyphilitic. The tannins is also found in bark used for dying.

Important pests:

1. Leaf hoppers: It is a major pest of mango that leads to major losses. So many species of this pest is wide spread throughout the world. The species of Amritodus are mostly spread in Indian subcontinent while some species of Idioscopus clypealis and I. nitidulus found in other Asian countries (Tandon and Verghese, 1985). The distribution of species varies within the country according to region. As per Veeresh 1989 I. clypealis and A. atkinsoni are major speceies in north India , I. nitidulus in south India and I. niveosparsus in Gujarat. The hoppers have broad head, narrow abdomen with wedge shaped body. The egg laying by female adult is 100-200 singly on tender leaves, flower buds and flowering shoots. The total life cycles is completed in about 15-19 days. The number of generations differ from place to place. During hot noon and rainy days the hopper took rest in cracks and crevices on the bark of mango (Patel *et al.*, 1973). The maximum population is reported during March-April. As per report of Tandon *et al.* (1983) the population of hoppers are also affected by abiotic factors like relative humidity, maximum and minimum temprature. The orchard having more plant population and dense vegetation have more hopper population (Srivastava, 1997: Reddy and Dinesh, 2005). The nymph and adult suck the sap from tender shoots and penicle resulting in withering and dropping of florets, reduces the fruitset and yield. It attracts sooty mould and formation of black kollesh and affects photosynthetic activity as per Butani (1979).

Management:

1. Maintain proper speacing during layout of orchard for proper light penetration in it and avoide overcrowding.
2. spray of biopesticides like neem oil 1% @ 3ml/litre.
3. In case of severe infestation spray of imidaclorpid 17. 8 SL @0. 3 ml/litre or thiamethoxam @05 g/litre. Spraying of chemical pesticides should be avoided during inflorscence emergence to save pollinators (Verghese and Devi Thangam, 2011).

2. Thrips: It suck the sap from new flushes , fruit, leaves and inflorscence and lacerating the tissues (Higgins 1992; Pena *et al.*, 2002). It reduces the fruit set, weaken the inflorescence and bronzing of fruit surface. It is more vsible on mature fruit (LEWIS 1973). The leaf tips get curled and turn brown in case of severe infestation (Aliakbarpour and CheSalmah, 2010). The population is incresing fasting during hot dry weather.

Management:

1. The monitoring of infestation should be done by placing sticky traps .

2. Regular spray of neem based pesticides.
3. Conservation of natural preadotrs like spiders, lacewings, ground beetles.
4. chemical spray with imidacloprid (0. 3 ml/litre) or spinosad (0. 25ml/l).

3. Mango leaf webbers: It is one of the serious pest in Bihar, Uttar pradesh and North India. Adult moths are medium sized and females lay their eggs on leaves. The catterpillars are damaging the plants by feeding on tender leaf chlorophyll by scraping the leaf surface. younge larve also feed by webing of leaves and cutting the leaves from edges to midrib. In severe infestation leaves become detached from the stalks. The pests completes so many generations from july to december on mango trees.

Management:

1. Prune the dead and affected parts and burn them.
2. Deep ploughing of orchard to damage the pupal stage by exposing to sunlight and natural enemies.
3. Spray contact insecticides like lamda cyhalothrin 1ml /litre.

4. Mealy bugs: It is a serious pest of mango in India and other Asian countries. Among different species Drosicha mangiferea is a polyphagous pest feeding on about 71 different plant speceies (Tandon, 1995; Srivastava, 1997). As per findings of Karar *et al.* 2012 the yield loss is up to 80 percent due to reduction in size and weight due to higher infestation. The damaging stage is nymph and femal adults. It adheres to the penicles and shoot and it becomes dried. Due to severe infestatio reduction in size and premature droping of fruits (Singh and Mukherjee, 1989). The main symptom of infestation is occurence of white cottony cushioned nymphs and adults (Mani, 2016).

Management:

1. Deep ploughing of orchard in November-December.
2. Apply Beauveria bassiana 2gm/litre in the second week of December around tree trunk.
3. Loosen the soil around the tree trunk in December and mix the chiorpyrifos dust 1. 5% @ 250gm per tree.
4. Clean the orchard and remove the weed plants that act as host plant for weed.

5. Scale insects: The female adult is damaging stage . It leads stationary life on different plant parts and suck the sap from it. As per findings of Rawat and Jakhmola (1970) the femals are fixed at same place throughout the life and by sucking cell sap and secerete wax like covring outside the body is called puparium. In case of severe infestation the fruit setting capacity and growth of the tree is adversly affected.

Management:

1. Prune and destroy the affected leaves and branches of the tree.
2. Use healthy palnting material free from infestation of scale insect.

3. Use natural preadators like *Cryptolaemus montrouzieri*.

6. Shoot gall Psylla: It is important monophagous pest of mango. As per findings of Singh (1960); Ahsan (1983) this pest was first reported from Bihar, Uttar Pradesh and Tarai regions of north India. Nymphs are damaging stage. Its infestation leads to formation of conical galls on apical and axillary buds due to its feeding inside the leaft midrib and chemical (probably phenyl amino acids) secretion. In later stage drying of infestated twigs and showing die-back symptoms (Singh *et al.,* 1975;Singh and Mishra, 1978).

Management:

1. Prune the infested shoot with gall symptom during September to check spread (Singh, 2000).
2. Spray of Dimethoate @1. 5 ml/litre.

7. Mites: It is a sporadic pests of mango. It colonozes on buds, leaves and fruits. Nymphs and adults are damaging stage in it suck the sap from leaves and tender shoots leads to leaf bronzing.

Management:Spray of wettable sulphur @2. 5gm /litre will be effective.

8. Shoot borer: It spreades all over India. The egg laying done by adult female on new tender leaves. After hatching of eggs larve bore into midribs of leaves and feed on it afterwards it enters tender shoots. After feeding it makes tunnel inside shoots. Its infestation is noticed by presence of excreata on shoots and entry point. In severe infestation wilting and drying of affected shoots. Incidence of this pest is maximum during July-October (Bhole *et al.,* 1987).

Management:

1. Prune the affected parts of plant and destroy it.
2. Spray of profenophos@1. 5ml/litre and neem oil @5 ml/litre at interval of 15 days at the time of new flush initiation.

9. Stem borer: It is one of the serious pest of mango in India. Among different species of borer Batocera rufomaculata is the most destructive and found everywhere in mango orchard. After egg hatching the larva feeds under the bark after that it makes tunnel through sapwood and interferes sap flow anf affects vegetative as well as reproductive growth. The tunnels are occure in the peripheral region as well as deep in the tree trunk. In initial stage damage is not noticiable . In severe infestation liquid is oozes out from hole on the branches and tree trunk. The are shedding from the branches drying and dieback of twigs and branches. The varitial prefrence of borer is also occure. As per findings of Palaniswamy *et al.* (1979); Reddy *et al.* (2015) Alphonso. Jehangir and Langra are most susceptible and Banganapalli and Himayuddin is least susceptible. The spacing of tree in orchard and rootstock also affects the borer population in orchard (Reddy *et al.,* 2015).

Management:

1. Prune the dead and affected parts of plants.
2. Remove and kill the grubs from the infected holeso n tree trunk by iron hooks.

3. Plugging the holes wth petrol or kerosene and pesting hole with mud kills the active larvae inside the stem.

10. Fruit flies: It is serious pest of mango in most part of the world leads to huge economic losses (Veeresh, 1989;Verghese *et al.*, 2011). It is one of the major constraint in exporting the fresh mangoes to foregin countries. In this female flies punctures the mature fruits and lays eggs in cluster inside it. After hatching of eggs maggots start feeding on pulp and makes the tunnel in it. The infected fruits are noticed by minute marks on the skin. Almost all the varities are susceptible of it. It is polyphagus in nature. It affects other fruit crops like guava. litchi, pomogranate, etc.

Management:

1. Collect the affected and fallen fuits from the orchard and destroy it regularly
2. Deep ploughing of orchard in November –December leads to exposure of pupae to hot sun and damaged by preadotrs .
3. Use of methyl eugenol bottles @ 6/acre.

Important Diseases:

1. Powdery mildew: It is serious disease affects both foliage and blossom. Heavy loss of mango crop by dropping of unfertilized infected flowers and immature fruits. Spraying of fungicides during flowring period reduces the incidence. In initial stage apperance of whitish grey mycelium appears on flowers and flower buds. In later stage it extendes to tender leaves, shoots and fruits. In advanced stage the whole surface is covered with powder like substance consisting of spores called condia. The conidial stage in this is known as *Oidium mangiferae*.

Management:

1. The spray of carbendazim or wettable sulphur controles the disease effectively.

2. Anthracnose:It is one of serious disease affecting leaves. As per findings of Bose *et al.* (1973) the palntation of Bombay green was fully eradicated in Tarai region of Utter Pradesh. It appears as oval or irregular brown to deep brown spots of different size widely spread on the leaf surface. Young leaves are more susceptible than older leaves. The affected petioles turn grey or black in color and ultimately droop down of leaves. After falling of leaves black scar appears on twig. It turns into black necrotic areas on the twigs. The most distructive phase of this disease is blossom blight. It affects fruit set and yield. The casual organism of this disease is *Colletotrichum gloeosporioides*. The optimum temprature for growth of this disease is 25 degree Celcius. The continious rainfall promotes the anthracnose incidence on mango fruits.

Management:

1. As per recommendation of Prakash and Srivastava (1987) the infected parts of the plants such as diseased leaves, twigs and fruits fallen in the orchard is collected and burnt.

2. The spray of Bordeaux mixture(4:4:50) at interval of 15 days till harvest(Tandon and Singh, 1968a).

3. Spray of Carbendazim (0. 1%) at interval of 15 days (Prakash and Mishra, 1988b)

3. Die-Back: It means death of the plants from tip to downwards. This affects large number of host plants. This disease is spreading day by day. This disease is noticeable allround the year but it is most promeninent from October to November (Prakash and Raoof, 1985b). Die-back of mango is occure due to Botryodiplodia theobromae in India (Prakash and Raoof, 1989; Rath *et al.*, 1978).

Management:

1. Prune the dead and diseased part of the plant and paste the cut end with Bordeaux mixture .

2. As per report of Sharma and Gupta (1994) the spray of 1% Bordeaux mixture and second spray with 0. 8% Bordeaux mixture and carbendazim is effective in controlling the die back disease.

4. Mango malformation: It is serious disease all over the world. It is also known as bunchy top. The work on this disease is happening since 1945 in India but still there is not any clear control measure for this remedy. This disease is more prevalent in northern India. More than 50% trees in north India is affected by this disease. This disease is first time reported from Darbhanga, Bihar by Maries in 1891. Differemt types of symptoms is observed in it such as vegetative malformation, floral malformation and bunchy top of seedlings. As per report of Varma, 1983 the symptom is divided in to two category as vegetative and floral malformation. Buchy top symptom appears on young plants during early stage. The seedling trees are more suceptible to malformation than grafted plants. The affected plants have excessive vegetative growth and having very short internodes. The spread of this disease is fast and may be distributed due to use of diseased plant for propagation (Varma *et al.*, 1971).

Management:

1. It is controlled by pruning and spraying of insecticides.

2. As per findings of Varma *et al.* (1971) the spray of systemic fungicides as preventive measure due to fungus situated in cortex phloem potion.

3. Potassium metabisulphite and NAA caused 92. 5% and 94% reduction in cv. Dashehari (Mehta *et al.*, 1986 and Siddiqui *et al.*, 1987).

However No. any definite control measures for this disease can be recommended but different control measures can reduce the incidence.

Conclusion:

We can say that alltough mango is one of the important fruit crop of India. It is cosumed in our country in various forms. Even its all parts are used in worship. There is some constraint in mango growing areas due to infestation of different diseases and pest.

References:

1. Ahsan, M. F. (1983). Incidence of the mango shoot-gall psyllid, *Apsylla cistellata* Bucjton at Shibganj. *University Journal of Zoology, 2*, 61-68.
2. Aliakbarpour, H., & CheSalmah, M. R. (2010). Diurnal activity of four species of thrips (*Thysanoptera: Thripidae*) and efficiencies of three nondestructive sampling techniques for thrips in mango inflorescences. *Journal of Economic Entomology, 103*, 631-640.
3. Bhole, S. D., Jadhav, V. S., Dumbre, R. B., & Dalvi, C. S. (1987). Seasonal incidence and chemical control of mango nursery pests in the Konkan region. *Journal of Maharashtra Agricultural University, 12*(3), 387-388.
4. Bose, S. K., Sindhan, G. S., & Pandey, B. H. (1973). Studies on die-back disease of mango in the Tarai region of Kumaon. *Progressive Horticulture, 5*, 41-53.
5. de Laroussilhe, F. (1980). *Le Manguier*. G. P. Masoneuve & Larose.
6. Higgins, C. J. (1992). Western flower thrips (*Thysanoptera: Thripidae*) in greenhouses: population dynamics, distribution on plants and association with predators. *Journal of Economic Entomology, 85*, 1891-1903.
7. Karar, H., Arif, M. J., Ali, A., Hameed, A., Abbas, G., & Abbas, Q. (2012). Assessment of yield losses and impact of morphological markers of various mango (*Mangifera indica*) genotypes on mango mealybug (*Drosicha mangifera* Green) (*Homoptera: Margarodidae*). *Pakistan Journal of Zoology, 44*(6), 1643-1651.
8. Lewis, T. (1973). *Thrips, their biology, ecology and economic importance*. Academic.
9. Mani, M. (2016). Fruit crops: mango. In M. Mani & C. Shivaraju (Eds.), *Mealy bugs and their management in agricultural and horticultural crops* (p. 385). Springer, New Delhi.
10. Mehta, N. J., Sandooja, J. K., Maddan, R. L., & Yamdagni, R. (1986). Role of different chemicals in mango malformation and related physiological factors. *Pesticides, 20*, 17-18.
11. Palaniswamy, M. S., Sundra, P. C., Babu, Subramanian T. R. (1979). Studies on the biology of mango stem borer, *Batocera rufomaculata* De Geer (*Coleoptera: Cerambycidae*). *South Indian Horticulture, 27*(3-4), 100-106.
12. Patel, A. K., Patel, S. R., & Shah, A. H. (1973). Studies on the sex ratio, longevity and seasonal incidence of mango leafhopper, *Amritodus atkinsoni* in South Gujarat. *Indian Journal of Entomology, 37*, 150-153.
13. Pena, J. E., Mohyuddin, A. I., & Wysoki, M. (1998). A review of the pest management situation in mango agroecosystems. *Phytoparasitica, 26*, 129-148.
14. Pena, J. E., Sharp, J. L., & Wysoki, M. (2002). *Tropical fruit pests and pollinators: biology, economic importance, natural enemies and control*. CABI Publishing, New York.
15. Prakash, Om, & Mishra, A. K. (1988). Evaluation of different fungicides for the control of anthracnose of mango. *International Journal of Tropical Plant Diseases, 6*, 225-229.

16. Prakash, Om, & Raoof, M. A. (1985). Dieback disease of mango and its control (Abstract). In *Proceedings of the Second International Symposium on Mango*, Bangalore, 9-14 Feb. (pp. 251-252).
17. Prakash, Om, & Raoof, M. A. (1989). Dieback disease of mango (*Mangifera indica*), its distribution, incidence, cause and management. *Fitopatologia Brasileira, 14*, 207-215.
18. Prakash, Om, & Srivastava, K. C. (1987). Mango diseases and their management - A world review. Today and Tomorrow's Printers and Publishers, New Delhi.
19. Rath, G. C., Swain, N. C., & Mohanan, M. K. (1978). A note on die back of mango in Orissa. *Indian Phytopathology, 31*, 384-386.
20. Rawat, R. R., & Jakhmola, S. S. (1970). Bionomics of the mango-coccid (*Rastrococcus iceryoides* Green; Homopetra: Coccidae). *Indian Journal of Agricultural Sciences, 40*(2), 140-144.
21. Reddy, P. V. R., & Dinesh, M. R. (2005). Evaluation of mango exotic collections for resistance to hopper, *Idioscopus niveosparsus* Lethierry India. *Journal of Plant Genetic Resources, 18*(1), 69-70.
22. Reddy, P. V. R., Varun Rajan, V., Thangam, D., & Chakravarthy, A. K. (2015). Stem borers in mango: Species diversity and damage patterns. In *Proceedings of the 4th Congress on Insect Science*, PAU Ludhiana, 16-17 April 2015 (pp. 150-151).
23. Sharma, I. M., & Gupta, V. K. (1994). Evaluation of different fungicides against *Botryodiplodia theobromae* Pat., causal organism of canker and die back of mango. *Indian Journal of Mycology and Plant Pathology, 24*(2).
24. Siddiqui, S., Sandooja, J. K., Mehta, N., & Yamadagni, R. (1987). Biochemical changes during malformation in mango cultivars as influenced by various chemicals. *Pesticides, 21*, 17-19.
25. Singh, S. M. (1960). Studies on mango shoot gall in Tarai region of UP. Its causes and control. II distribution, nature, extent, intensity of damage and binomics of the pest. *Horticultural Advances (Horticultural Research Institute, Saharanpur), 4*, 97-114.
26. Singh, G. (2000). Physiology of shoot gall formation and its relationship with juvenility and flowering in mango. In *VI International Symposium on Mango* (pp. 803-810).
27. Singh, G., & Mishra, P. N. (1978). The mango shoot gall psyllid *Apsylla cistellata* Buckton and its control. *Pesticides, 12*, 15-16.
28. Singh, J., & Mukherjee, I. N. (1989). Pest status of phytophagous mites in some northern states of India. In *Proceedings of the First Asia-Pacific Conference of Entomology*, Chiang Mai, Thailand (pp. 192-203).

29. Singh, G., Kumar, A., & Everrett, T. R. (1975). Biological observations and control of *Apsylla cistellata* Buckton (*Psyllidae: Homoptera*). *Indian Journal of Entomology, 37*, 46-50.
30. Srivastava, R. P. (1997). *Mango Insect Pest Management* (No. Ed. 1). International Book Distributing Co., Lucknow.
31. Tandon, I. N., & Singh, B. B. (1968). Control of mango anthracnose by fungicides. *Indian Phytopathology, 21*, 212-216.
32. Tandon, P. L. (1995). Integrated insect pest management in mango. In Proceedings of the National Symposium on Integrated Pest Management and Environment, organized by Plant Protection Association of India and FAO at Madras, 2-4 February 1995.
33. Tandon, P. L., & Verghese, A. (1985). World list of insect, mite and other pests of mango, Technical Document, vol. 5. Indian Institute of Horticultural Research, Bangalore.
34. Tandon, P. L., Lal, B., & Rao, G. S. P. (1983). Prediction of mangohopper Idioscopus clypealis (Leth.) population in relation to physical environmental factors. Entomon, 8, 257-261.
35. Varma, A. (1983). Mango malformation. In Exotic Plant Quarantine Pest and Procedure for Introduction of Plant Material (pp. 173-188).
36. Varma, A., Raychaudhury, S. P., Lele, V. C., & Ram, A. (1971). Preliminary investigations on epidemiology and control of mango malformation. Proceedings of the Indian Horticultural Science Academy, 37(B), 291-300.
37. Veeresh, G. K. (1989). Pest problems in mango - world situation. Acta Horticulturae, 231, 551-565.
38. Verghese, A., & Devi Thangam, S. (2011). Mango hoppers and their management. Extension folder no:71-11, ATIC series:31-11. Indian Institute of Horticultural Research, Bangalore.

A REVIEW OF BIOLOGICALLY ACTIVE SUBSTANCES AND PROCESSING TECHNIQUES FOR SESAME SEEDS

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Abstract:

Sesame seeds are considered high-quality edible oil crops due to their high lipid (40-65%), protein (19-35%), and bioactive component content. The review begins with the bioactive components of sesame seeds (fatty acids, tocopherol, phytosterol, sesamin, sesamolin, and sesamol). It discusses procedures for obtaining oil from seeds (aqueous extraction and pressing). Novel approaches, including enzyme-assisted aqueous, supercritical CO_2, and microwave-assisted solvent extraction, are also discussed. Sesame seed cake is examined for its various applications. Future sesame seed processing technology will focus on enhancing utilization rates to suit rising consumption demands.

Introduction:

Sesame (*Sesamum indicum* L.), annual herb, belonging to leguminous and sesame genu, Pedaliaceae, is a traditional crop widely cultivated in India, Sudan, China, and Burma. As a traditional medicinal plant with high nutrition value and flavor, sesame has been loved by people, and plays an extremely important role. As a traditional oil crop, sesame was recognized as one of the four largest edible oil crops in China along with soybean, peanut, and rape (Shao *et al*., 2020). Sesame is known as the "Queen of oilseed" and "orphan crop" due to its high oil content attractive aroma and degree of resistance to oxidation and rancidity (Mujtaba *et al*., 2020). The high interests of sesame seed might be explained by its abundant sesame lignans, mainly including a high content of sesamin, sesamolin and sesamol. Because of the higher content of lignan, phytosterol, tocopherol and other components, sesame oil shows antioxidant and health promotion effects. The International Institute for Plant Genetic Resources (IPGRI) considers sesame to have significant development potential and classifies it as a neglected and underused crop (Shao *et al.*, 2020). The co-products obtained from sesame as the major raw material are mostly utilized in the manufacturing of various food items, soaps, lubricants, industrial supplies, medical and animal feed (Myint *et al.*, 2020).

Currently, the fundamental characteristics of sesame processing in China are primary processing and continual improvement of deep processing technology. Although tiny sesame processing workshops are still common, firms' processing capacity is gradually increasing.

Nutritional properties of sesame

Sesame is rich in antioxidants and bioactive compounds including lignans, phytosterols, fatty acid, and tocopherols. Sesame oil has higher anti-oxidant compared to other edible oils, which increases energy and prevents aging. Sesamol is a degradation product and nutritional component of lignan from sesame. It is an important aroma component and quality stabilizer of sesame oil, which has been identified as a new antioxidative substance in sesame oil. Sesamol has been reported to be used in antioxidant, lipid-lowering, antidepressant activities, diabetic nephropathy, and neuropathy. In addition, it also has been widely studied as anti-inflammatory, anti-atherosclerotic hardener or heart protection agent. Sesamol was used to resists insulin in the central nervous system which blocks learning and memory. Sesamin is also one of the main lignans in sesame, and is considered to have anti-proliferative, pro-apoptotic, anti-inflammatory, anti-metastatic, pro-angiogenic, and ant-oxidant effects, and pro-autophagocytic activities. It also has a protective effect on blood pressure, blood glucose, and lipid oxidation levels. Sesamolin has long been known as a representative lignan in sesame oil, which showed significant antioxidant, anti-aging, and anti-mutagenic properties. Based on a wehi-3B-induced leukemia model, Nagarajan and Lee (2021) demonstrated that sesamolin shows considerable potential as a novel anti-leukemic agent effect in vivo. Fatty acid composition is the main determinant for the quality of edible oils and is the critical parameter for the consumption of oilseed (Parsaeian *et al.*, 2020). Oleic and linoleic acids are the predominant unsaturated fatty acids in sesame oil, and they account for more than 80% of the total fatty acids. Polyunsaturated fatty acids (PUFAs) of the n-3 series are the necessity of our life. And n-6 fatty acid and n-3 fatty acid play essential roles in prevention of diseases, such as diabetes, arthritis, hypertension, and cancer. Reported that PUFAs have antiarrhythmic, anti-inflammatory, hypolipidemic, anti-thrombotic, and vasodilatory physiological activity.

Processing of sesame

Aqueous extraction method can extract protein and oil at the same time, which has the advantages of good oil quality, simple equipment, and production process, less investment, and flexible production scale. Hou *et al.* (2013) determined the optimal conditions for sesame oil extraction as follow, solid to water ratio of 0.8 g/mL (V/m), 70C and pH 5.0, under which the extraction rate reached 82.49%. Mechanical pressing has the advantages of simple operation, safety, and low cost, and is usually used for the extraction of seeds with high oil content; the oil obtained by this method has good quality. Enzymatic aqueous extraction is a clean, non-toxic process with mild reaction conditions, with low equipment requirements, and is proved to be an alternative method for extracting sesame oil. Ribeiro *et al.* (2016) reported that enzymatic aqueous extraction compared to conventional extraction methods not only improved the quality of sesame oil but also applied a green and free of toxic solvents. The method of extraction with carbon dioxide in a supercritical state can effectively avoid destruction of high-temperature oxidation and retain rich nutrition and physiological activity of oil (Li *et al.*, 2020). The chemical characteristic, oxidative stability, and in vitro antioxidant capacity of sesame oil were studied by supercritical and subcritical techniques, the results showed that a large proportion of fatty acid and triacylglycerol were not significantly influenced by the processing technologies. Microwave-assisted extraction uses electromagnetic waves. With the increase of temperature, solvent molecules in the cell evaporate rapidly, and the pressure generated in the cell breaks cell wall, so that the contents in the cell flow out quickly. Optimized the effects of solvent-based microwave-assisted extractions of sesame phenolic compounds, and the results showed that the maximum total phenolic content was 206.14 mg GAE/100 g.

Use of co product of sesame

Sesame oil processing generates byproducts such as sesame cake and residue. The cake and leftovers are high in proteins. Researchers have isolated sesame protein from industrial co-products and used it to create bioactive sesame proteins. reported that sesame's bioactive peptide had the function of lowering cholesterol and promoting fat metabolism, which showed the potential application in the food, medical, and feed industry. Pointed out that sesame peptides could be used as raw materials for the development of new functional foods and health products. If the protein in sesame is made into a protein supplement, it can reduce the processing cost of sesame and accelerate the sustainable development of the sesame processing industry. The rapid growth of global energy consumption and fuel demand is increasing, more and more attention has been paid to the development of new energy sources such as renewable, green, and sustainable biofuels (Mujtaba *et al.*, 2021).

In addition to being used for direct consumption, sesame can also be used for production of biofuel with oil. Mujtaba et al. (2020) pointed out that the biofuel extracted from sesame can be used to produce second-generation biodiesel, and then used to produce bioethanol from sesame plant residue is a novel research direction. Some scientists in Europe and the United States have determined a series of stability and other performance indexes of biodiesel produced by sesame oil and proved that sesame biodiesel can be used as a potential raw material for development. The lignocellulose contained in sesame can be used to produce low-cost bioethanol, and the hydrolyzed lignocellulose plays an important role in the production of alternative fuels and other new energy sources.

Conclusion:

Sesame seed contains numerous health-promoting phytochemicals, including sesamin, sesamolin, tocopherols, PUFA, phytosterols, and phenolics. Ultrasonic/microwave-assisted extraction is a popular pretreatment procedure for sesame seeds. Improving production methods can improve product quality, nutritional composition, and other metrics, leading to improved utilization of by-products. Sesame's new technology is still in its early stages and requires more development. During the process of extracting and refining, nutritional value of sesame oil is usually reduced, and some impurities and risk factors are also produced. Therefore, in further research, the following processing principles should be considered, as high efficiency, green environmental protection, energy-saving, standardized production technology, and strict quality standards, in order to retain original flavor and nutrients of sesame oil in the products. Meanwhile, the by-products should make better use of sesame processing for more comprehensive benefits.

References:

1. Mujtaba, M.A., Muk Cho, H., Masjuki, H.H., Kalam, M.A., Ong, H.C., Gul, M., Harith, M.H., Yusoff, M.N.A.M., (2020). Critical review on sesame seed oil and its methyl ester on cold flow and oxidation stability. Energy Rep. 6, 40–54.
2. Mujtaba, M.A., Kalam, M.A., Masjuki, H.H., Soudagar, M.E.M., Khan, H.M., Fayaz, H., Farooq, M., Gul, M., Ahmed, W., Ahmad, M., *et al.,* (2021). Effect of palm-sesame biodiesel fuels with alcoholic and nanoparticle additives on tribological characteristics of lubricating oil by four ball tribo-tester. Alex. Eng. J. 60, 4537–4546.
3. Li, X.M., Jiang, S.B., Zhang, Y., Zhang, Q., Shao, J.J., (2020). Application of supercritical CO2 extraction technology in food. J. Cereals Oilseeds 33 (1), 18–20.
4. Ribeiro, S.A.O., Nicacio, A.E., Zanqui, A.B., Biondo, P.B.F., de Abreu-Filho, B.A., Visentainer, J.V., Gomes, S.T.M., Matsushita, M., (2016). Improvements in the quality of sesame oil obtained by a green extraction method using enzymes. LWT - Food Sci. Technol. (Lebensmittel-Wissenschaft -Technol.) 65, 464–470.
5. Hou, R.C.W., Huang, H.M., Tzen, J.T.C., Jeng, K.C.G., (2003). Protective effects of sesamin and sesamolin on hypoxic neuronal and PC12 cells. J. Neurosci. Res. 74, 123–133.
6. Parsaeian, M., Shahabi, M., Hassanpour, H., (2020). The integration of image processing and artificial neural network to estimate four fatty acid contents of sesame oil. LWT 129, 109476.
7. Nagarajan, S., Lee, J.K., (2021). Therapeutic effects of sesamolin on leukemia induced by WEHI-3B in model mice. Appl. Biol. Chem. 64, 45.
8. Myint, D., Gilani, S.A., Kawase, M., Watanabe, K.N., (2020). Sustainable sesame (Sesamum indicum L.) production through improved technology: an overview of production, challenges, and opportunities in Myanmar. Sustainability 12 (9).
9. Shao, J.W., Zhang, G.X., Fu, J.X., Zhang, B.W., (2020). Advancement of the preparation methods and biological activity of peptides from sesame oil byproducts: a review. Int. J. Food Prop. 23, 2189–2200.

LEVERAGING ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE AND PROTECTIVE AGRICULTURE: A REVIEW AND PROSPECTIVE OUTLOOK

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Abstract:

Artificial Intelligence (AI) is revolutionizing agriculture by providing innovative solutions for sustainable and protective farming practices. This review paper presents a widespread role of AI in agriculture, focusing on its applications in promoting sustainability, enhancing crop protection, and mitigating environmental impacts. AI subsets such as machine learning, Internet of Things (IoT), and robotics are added into agricultural practices, highlighting their potential to enhance the utilization of resources, reduction of environmental risks, and ensuring the food security for future generations.

Introduction:

Agriculture is experiencing a revolution steered by technological advancements, with AI emerging as a key enabler of green and protective agricultural practices. By controlling the influence of data analytics, automation, and smart decision-making, AI offers solutions to address the challenges facing modern agriculture, including climate change, soil degradation, water scarcity, and pest outbreaks. In this paper, we explore the role of AI in promoting sustainability and protecting crops, ecosystems, and livelihoods in agricultural systems worldwide.

AI technologies are applied across various domains of sustainable agriculture, including precision farming, smart irrigation, crop monitoring and climate resilience [1]. In precision farming, AI-based systems analyse satellite imagery, weather data, and soil information to optimize planting, irrigation, and fertilization practices, leading to resource efficiency and higher yields. The smart irrigation deals with the IoT-enabled sensor and AI algorithms that monitor soil moisture levels and weather patterns in real-time, enabling accurate irrigation development and dropping water wastage. In crop monitoring, computer vision and machine learning algorithms analyse drone imagery and remote sensing data to examine crop strength, sense diseases and assess the potency of yield, facilitating early intervention and crop management decisions [2]. In climate resilience, AI-powered predictive models forecast climate patterns, extreme weather events, and crop yields, helping farmers adapt to changing environmental conditions and mitigate risks.

Precision farming

Precision farming relies on the principles of spatial and temporal variability, recognizing that different parts of a field may have unique characteristics and requirements. Key principles deal with tailoring inputs such as pesticides, water and fertilizers based on the explicit demands of discrete areas inside a field. Data-driven decision-making is important by utilizing various data sources such as satellite imagery, sensors and weather conditions predictions to inform management conclusions. Regular monitoring of crop is followed to monitor the health, soil conditions, and environmental factors.

GPS and other satellite systems enable precise mapping and tracking of field boundaries, crop health, and machinery. Satellite and drone-based imagery provide effective perceptions into the strength of crop, level of nutrient and infestations of pest. Soil sensors, weather stations and crop sensors are used to collect instantaneous data sets on temperature, soil dampness and plant growth. Advanced algorithms analyse large datasets to identify patterns, predict crop performance and optimize management strategies.

Precision farming offers numerous benefits to farmers, consumers, and the environment [3]. Optimized resource use leads to higher yields and lower input costs. Reduced chemical usage, erosion, and nutrient runoff mitigate environmental impact. Precise management practices result in higher-quality crops with fewer defects.

Despite its potential, precision farming faces several challenges also. Initial investment in knowledgebase and data organization can be prohibitive for small-scale farmers. Integrating and analysing large volumes of data requires specialized skills and infrastructure. Limited awareness, technical knowledge, and support networks may hinder widespread adoption. Privacy concerns and data ownership issues raise ethical questions about the use of technology in agriculture.

Smart irrigation

AI-based smart irrigation systems represent a transformative approach to water management in agriculture, offering a powerful tool for enhancing sustainability, productivity and resilience in the face of mounting water challenges [4]. While obstacles remain, ongoing innovation and collaboration hold the key to exposing the full capacity of AI in optimizing water use and securing the opportunity of food production. The technologies driving AI-based smart irrigation systems consists of sensor networks, IoT, cloud computing and AI algorithms. Soil moisture sensors, crop sensors and weather observation and control stations provide actual data on green conditions and crop water requirements. IoT based connected devices transmit data to centralized platforms for analysis and decision-making. High-performance computing enables processing of large datasets and implementation of complex algorithms.Machine learning techniques such as neural networks, decision trees, and reinforcement learning optimize irrigation scheduling and water management.

Role of AI in crop protection

AI plays a crucial role in safeguarding crops against pests, diseases, and invasive species through early detection in which AI algorithms analyse sensor data, satellite imagery, and historical records [5] to detect pest outbreaks and disease symptoms at early stages, enabling timely intervention and containment.Machine learning models predict pest infestations, crop diseases, and weed growth patterns based on environmental factors, crop characteristics, and pest life cycles, guiding proactive pest management strategies.Robotics and AI-enabled drones deliver targeted interventions such as precision spraying, biological pest control, and pheromone-based trapping, minimizing pesticide usage and environmental impact.

Environmental sustainability, ethical considerations and future directions

While AI offers numerous benefits for sustainable and protective agriculture, it also raises concerns related to data privacy, algorithm bias, and environmental impact [6]. It is essential to address these challenges through transparent and accountable AI governance frameworks, ethical guidelines, and stakeholder engagement to ensure that AI technologies contribute to the long-term sustainability of agriculture.

Future research directions in AI for sustainable and protective agriculture include integration of emerging technologies, knowledge sharing and capacity building and policy support and regulation [7]. Combining AI with blockchain, edge computing, and renewable energy sources can further enhance agricultural sustainability and resilience.Promoting knowledge exchange, capacity building, and technology transfer among farmers, researchers, and policymakers can accelerate the adoption of AI-driven agricultural practices [8].Governments and international organizations need to develop policies and regulations that promote responsible AI adoption, protect farmers' rights, and safeguard environmental resources.

Conclusion:

AI has the ability to change agriculture into a highly resilient, ecological and protective enterprise. By harnessing AI technologies for precision farming, crop protection, and environmental management, we can address the complex challenges facing global food systems while ensuring the longstanding capability of farming ecosystems. However, grasping the full capacity of AI for sustainable farming requires collaboration, innovation, and ethical stewardship to balance technological advancement with social, environmental, and economic considerations.

References:

1. Lopes, L. M., Garcia, L. P. S., & de Souza, A. L. F. (2020). Artificial intelligence for sustainable agriculture: A review. Journal of Cleaner Production, 258, 120541.

2. Kamilaris, A., Prenafeta-Boldú, F. X., & Liotta, A. (2017). Applications of machine learning in real-life digital agriculture: A review. MDPI Electronics, 6(2), 24.
3. Kassam, A., Friedrich, T., Derpsch, R., & Lahmar, R. (2019). Conservation agriculture. Nature Reviews Earth & Environment, 1(7), 318-330.
4. Thangamani, R., Sathya, D., Kamalam, G. K., & Lyer, G. N. (2024). AI Green Revolution: Reshaping Agriculture's Future. In Intelligent Robots and Drones for Precision Agriculture (pp. 421-461). Cham: Springer Nature Switzerland.
5. Balaska, V., Adamidou, Z., Vryzas, Z., &Gasteratos, A. (2023). Sustainable crop protection via robotics and artificial intelligence solutions. Machines, 11(8), 774.
6. Gupta, M., Abdelsalam, M., Khorsandroo, S., & Mittal, S. (2020). Security and privacy in smart farming: Challenges and opportunities. IEEE access, 8, 34564-34584.
7. Dayıoğlu, M. A., & Turker, U. (2021). Digital transformation for sustainable future-agriculture 4.0: A review. Journal of Agricultural Sciences, 27(4), 373-399.
8. Steinke, J., Van Etten, J., Müller, A., Ortiz-Crespo, B., van de Gevel, J., Silvestri, S., & Priebe, J. (2021). Tapping the full potential of the digital revolution for agricultural extension: an emerging innovation agenda. International Journal of Agricultural Sustainability, 19(5-6), 549-565.

CLIMATE-RESILIENT AGRICULTURE: AI AND REMOTE SENSING

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Introduction:

Climate change poses significant challenges to global agriculture, threatening food security, livelihoods, and environmental sustainability. In response, innovative technologies such as artificial intelligence (AI) and remote sensing offer promising solutions for enhancing agricultural resilience to climate variability and extremes. This chapter explores the integration of AI and remote sensing techniques to advance climate-resilient agriculture, examining their applications, methodologies, and implications for sustainable food production in a changing climate.

the challenges: A climate under siege

The agricultural sector is intricately linked to climate and highly susceptible to its fluctuations. Here's a glimpse into some of the key challenges posed by climate change:

- **Increased variability:** Erratic weather patterns, including more frequent droughts, floods, and extreme heat events, disrupt traditional planting and harvesting cycles, leading to crop failures and yield losses.
- **Water scarcity:** Rising temperatures and changing precipitation patterns are leading to water scarcity in many agricultural regions. This poses a significant threat to crop irrigation and overall agricultural productivity.
- **Soil degradation:** Increased frequency of droughts and floods can accelerate soil erosion, impacting soil fertility and its ability to support healthy plant growth.
- **Pest and disease outbreaks:** Changing climatic conditions can alter the distribution and prevalence of agricultural pests and diseases. Warmer temperatures can lead to the emergence of new pest and disease threats, further jeopardizing crop yields.

These challenges threaten not only global food security but also the livelihoods of millions of farmers worldwide.

Understanding climate-resilient agriculture

Climate-resilient agriculture encompasses a suite of strategies and practices aimed at enhancing the adaptive capacity of farming systems to withstand climate-related stresses and shocks. Key components of climate-resilient agriculture include:

1. **Crop diversification**: Cultivating diverse crop varieties with varying tolerance to temperature, precipitation, and pest pressures helps mitigate the risks of climate-related yield losses and enhances ecosystem resilience.

2. **Precision agriculture**: Utilizing precision farming technologies such as GPS, GIS, and remote sensing enables targeted management of inputs, optimizing resource use efficiency and minimizing environmental impacts.
3. **Water management**: Implementing efficient irrigation techniques, rainwater harvesting, and soil moisture monitoring systems helps conserve water resources, reduce vulnerability to drought, and sustain crop productivity in water-stressed regions.
4. **Soil conservation**: Adopting soil conservation practices such as conservation tillage, cover cropping, and agroforestry improves soil health, mitigates erosion, and enhances carbon sequestration, contributing to climate change mitigation and adaptation.
5. **Climate-smart technologies**: Deploying climate-smart technologies such as drought-resistant crop varieties, weather-indexed insurance, and early warning systems enhances farmers' adaptive capacity and resilience to climate risks.

The promise: AI and remote sensing to the rescue

AI and remote sensing technologies offer a powerful toolkit for building climate-resilient agricultural systems. Artificial intelligence (AI) holds immense potential for revolutionizing agriculture by offering data-driven insights, predictive analytics, and decision support tools for optimizing farm management practices and enhancing resilience to climate change. Let's explore these technologies in detail:

The role of artificial intelligence in climate-resilient agriculture

Artificial intelligence (AI) encompasses a range of technologies and algorithms that enable machines to simulate human-like intelligence, learn from data, and make decisions or predictions. In agriculture, AI holds immense potential for optimizing farm management practices, enhancing productivity,

and mitigating climate risks. Key applications of AI in climate-resilient agriculture include:

1. **Climate modeling and prediction**: AI algorithms analyze historical climate data, satellite imagery, and meteorological forecasts to develop predictive models of future climate scenarios. These models enable farmers to anticipate and mitigate climate risks such as droughts, floods, and heat waves, allowing for timely adaptation and decision-making.
2. **Crop monitoring and yield prediction**: AI-powered remote sensing platforms and unmanned aerial vehicles (UAVs) capture high-resolution imagery of agricultural landscapes, enabling real-time monitoring of crop health, growth, and yield potential. Machine learning algorithms analyze these data to generate yield forecasts, optimize input usage, and detect crop stressors such as pests, diseases, and nutrient deficiencies.
3. **Smart irrigation management**: AI-based irrigation systems use sensors, actuators, and predictive analytics to optimize water application, scheduling, and distribution based on

crop water requirements, soil moisture levels, and weather forecasts. By minimizing water wastage and maximizing irrigation efficiency, these systems enhance drought resilience and water resource management in agricultural landscapes.

4. **Pest and disease detection**: AI algorithms trained on image recognition and pattern analysis can identify pest infestations, plant diseases, and weed pressures in crops, enabling early detection and targeted interventions to prevent yield losses and minimize pesticide usage. Integrated pest management (IPM) strategies informed by AI technologies promote ecological balance and reduce environmental risks associated with chemical inputs.
5. **Supply chain optimization**: AI-powered supply chain management systems optimize logistics, transportation, and storage operations, reducing post-harvest losses, improving market access, and enhancing food security. Predictive analytics and demand forecasting algorithms enable efficient resource allocation and distribution of agricultural products, particularly in remote and vulnerable regions.

The role of remote sensing in climate-resilient agriculture

Remote sensing involves the collection and analysis of data from satellites, aircraft, and ground-based sensors to monitor and analyze the Earth's surface and atmosphere. In agriculture, remote sensing technologies provide valuable information on crop health, soil moisture, land use, and environmental conditions, supporting decision-making processes and enhancing agricultural resilience. Key applications of remote sensing in climate-resilient agriculture include:

1. **Vegetation monitoring**: Remote sensing platforms capture multispectral and hyperspectral imagery of agricultural landscapes, allowing for the assessment of vegetation indices such as normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI). These indices provide insights into crop health, biomass production, and photosynthetic activity, enabling farmers to monitor crop growth and detect stressors such as water shortage, nutrient deficiency, and pest infestation.
2. **Land use mapping**: Remote sensing data can be used to map land cover and land use patterns, identifying changes in agricultural practices, deforestation, urbanization, and natural habitats. These maps inform land management decisions, conservation strategies, and policy interventions aimed at promoting sustainable land use and ecosystem conservation.
3. **Soil moisture monitoring**: Remote sensing techniques such as radar and thermal imaging can measure soil moisture content and surface temperature, providing valuable information on soil water availability, evapotranspiration rates, and drought conditions. These data support irrigation management, crop planning, and water resource allocation strategies, enhancing agricultural resilience to climate variability and water stress.

4. **Crop yield estimation**: Remote sensing-based models and algorithms integrate satellite imagery, weather data, and crop growth parameters to estimate crop yields and production potential. These models enable farmers, policymakers, and agribusinesses to forecast harvests, assess market dynamics, and make informed decisions regarding crop selection, planting schedules, and market strategies.
5. **Environmental monitoring**: Remote sensing data can be used to monitor environmental indicators such as air quality, water quality, and habitat degradation, providing insights into ecosystem health and resilience. These data support conservation efforts, pollution control measures, and climate change adaptation strategies, safeguarding natural resources and biodiversity in agricultural landscapes.

Methodologies and techniques

The integration of artificial intelligence and remote sensing techniques in climate-resilient agriculture involves several methodologies and techniques, including:

1. **Data collection**: Collecting high-quality, high-resolution data from satellite imagery, UAVs, ground-based sensors, and weather stations is essential for training AI algorithms, calibrating models, and validating predictions. Data preprocessing steps such as image correction, geometric rectification, and spectral normalization ensure consistency and accuracy in data analysis.
2. **Algorithm development**: Developing AI algorithms and machine learning models requires careful selection of features, training data, and optimization techniques. Supervised learning approaches such as support vector machines (SVM), random forests, and deep learning neural networks are commonly used for classification, regression, and clustering tasks in remote sensing applications.
3. **Model validation**: Validating AI models and remote sensing products involves comparing predicted outputs with ground truth observations, field measurements, and reference datasets. Cross-validation techniques such as k-fold validation, leave-one-out validation, and bootstrapping assess model performance and generalization capabilities across different spatial and temporal scales.
4. **Spatial analysis**: Spatial analysis techniques such as spatial autocorrelation, spatial interpolation, and spatial clustering are used to analyze and visualize patterns, trends, and relationships in remote sensing data. Geographic information systems (GIS) and geostatistical methods facilitate spatial data integration, geospatial analysis, and decision support for agricultural planning and management.
5. **Temporal analysis**: Temporal analysis of remote sensing time series data enables monitoring of seasonal vegetation dynamics, phenological changes, and land surface processes over time. Time series analysis techniques such as trend analysis, seasonal

decomposition, and anomaly detection identify long-term trends, seasonal patterns, and anomalies in remote sensing observations, informing climate change adaptation strategies and risk management decisions.

Benefits and challenges:

The integration of artificial intelligence and remote sensing techniques offers numerous benefits for climate-resilient agriculture, including:

- **Enhanced decision-making**: AI algorithms and remote sensing technologies provide farmers, policymakers, and stakeholders with timely, accurate, and actionable information for optimizing agricultural practices, minimizing risks, and maximizing productivity under changing environmental conditions.
- **Resource efficiency**: Precision agriculture techniques informed by AI and remote sensing data optimize resource use efficiency, reduce input costs, and minimize environmental impacts, promoting sustainable land management practices and conservation of natural resources.
- **Risk reduction**: Early warning systems, predictive analytics, and climate modeling tools based on AI and remote sensing enable proactive risk management, helping farmers anticipate and mitigate climate-related hazards such as droughts, floods, and extreme weather events.
- **Innovation and adaptation**: AI-driven innovations in agriculture and remote sensing technologies foster research, development, and collaboration across interdisciplinary fields, catalyzing the adoption of climate-resilient technologies, practices, and policies to address emerging challenges.

However, the integration of AI and remote sensing in climate-resilient agriculture also poses certain challenges, including:

- **Data availability**: Access to high-quality, high-resolution data from satellites, UAVs, and ground-based sensors is essential for training AI algorithms and validating remote sensing products. Ensuring data availability, interoperability, and affordability is critical for equitable access to technology-driven solutions, particularly among smallholder farmers and resource-constrained communities.
- **Data quality and accuracy**: Maintaining data quality and accuracy in remote sensing observations, AI models, and predictive analytics requires rigorous validation, calibration, and quality assurance processes. Addressing issues such as sensor calibration errors, atmospheric correction artifacts, and ground truth validation biases is essential for reliable and trustworthy results.
- **Technical capacity**: Building technical capacity and digital literacy skills among farmers, extension agents, and agricultural stakeholders is essential for effectively

utilizing AI tools and remote sensing technologies. Training programs, capacity-building initiatives, and user-friendly interfaces can facilitate technology adoption and empower end-users to harness the benefits of technology-driven innovations in agriculture.

- **Ethical and social implications**: Addressing ethical concerns such as algorithmic bias, data privacy, and digital divide is critical for promoting responsible and inclusive deployment of AI and remote sensing technologies in agriculture. Engaging stakeholders in participatory decision-making processes, transparent governance structures, and regulatory frameworks can mitigate potential risks and ensure the equitable distribution of benefits from technology-driven innovations.

Case studies and best practices

Several initiatives and projects around the world are leveraging AI and remote sensing technologies to promote climate-resilient agriculture and enhance food security. For example:

1. **NASA harvest**: NASA Harvest is a global agricultural monitoring initiative that utilizes satellite imagery, AI algorithms, and ground-based observations to monitor crop conditions, yield forecasts, and food production trends. By providing timely and accurate information to farmers, policymakers, and humanitarian organizations, NASA Harvest helps improve agricultural resilience, food security, and disaster response efforts worldwide.
2. **Digital Agriculture Services (DAS)**: Digital Agriculture Services is a technology company that develops AI-powered decision support tools for farmers and agribusinesses. Their platform integrates satellite imagery, weather data, and machine learning algorithms to provide personalized recommendations for crop management, input optimization, and risk mitigation strategies, empowering farmers to make informed decisions and improve productivity.
3. **Climate Smart Agriculture Prioritization Tool (CSAPT)**: CSAPT is a web-based decision support tool developed by the International Maize and Wheat Improvement Center (CIMMYT) to prioritize climate-smart agricultural interventions in vulnerable regions. The tool integrates climate data, agronomic models, and socio-economic indicators to identify high-potential areas for adopting climate-resilient crops, conservation practices, and water management strategies, guiding investment and policy decisions for sustainable agricultural development.
4. **FarmBeats (Microsoft)**: FarmBeats is an AI-driven platform that integrates data from sensors, drones, and satellites to provide farmers with actionable insights for optimizing irrigation, fertilization, and pest management practices. By harnessing AI technologies, FarmBeats aims to increase agricultural productivity, conserve natural resources, and improve livelihoods in rural communities.

5. **Digital Green**: Digital Green is a non-profit organization that uses AI-powered video dissemination platforms to deliver agricultural extension services and training to smallholder farmers in remote areas. By leveraging AI algorithms for content recommendation and user engagement, Digital Green enhances knowledge sharing, technology adoption, and social learning among farming communities, leading to improved agricultural practices and livelihood outcomes.
6. **WeatherAI (IBM)**: WeatherAI is a weather forecasting platform that utilizes AI algorithms to generate hyper-localized weather predictions and climate projections for agricultural regions. By providing farmers with accurate and timely weather information, WeatherAI helps optimize planting schedules, irrigation management, and crop protection measures, reducing climate-related risks and enhancing farm resilience.

India's climate-resilient agriculture: Harnessing AI & remote sensing

India's agriculture sector is facing unprecedented challenges due to the impacts of climate change, including erratic rainfall, rising temperatures, and extreme weather events. In response, there is a growing need to adopt innovative technologies to enhance the resilience of agricultural systems. India has made significant strides in leveraging artificial intelligence (AI) and remote sensing technologies to enhance climate-resilient agriculture. Here are some key innovations and initiatives in this field:

1. **Crop monitoring and prediction:** Various Indian organizations, including the Indian Council of Agricultural Research (ICAR) and Indian Space Research Organisation (ISRO), have developed AI-based models for crop monitoring and yield prediction. These models utilize satellite imagery, weather data, and machine learning algorithms to provide timely information to farmers about crop health, growth stages, and yield estimates. Such tools help farmers make informed decisions regarding irrigation, fertilization, and pest management, thereby improving productivity and resilience.
2. **Drought monitoring and early warning systems:** In drought-prone regions of India, remote sensing data is used to monitor soil moisture levels, vegetation health, and water availability. AI algorithms analyze satellite images to detect early signs of drought stress in crops and vegetation. Organizations like ISRO and the National Remote Sensing Centre (NRSC) have developed drought early warning systems that provide alerts to farmers and policymakers, enabling proactive measures to mitigate the impact of drought on agriculture.
3. **Precision agriculture and resource management:** AI and remote sensing technologies are being applied in precision agriculture to optimize resource use and minimize environmental impact. Farmers can use drones equipped with remote sensing sensors to collect high-resolution imagery of their fields, which is then analyzed using AI

algorithms to identify areas of nutrient deficiency, pest infestation, or water stress. This information enables targeted interventions, such as variable-rate fertilization and irrigation, leading to more efficient resource management and improved crop resilience.

4. **Climate-resilient crop varieties:** Indian agricultural research institutions are using AI and remote sensing data to develop climate-resilient crop varieties through breeding programs. By analyzing historical weather data and satellite imagery, researchers identify traits associated with climate resilience, such as drought tolerance, heat resistance, and disease resistance. AI algorithms are then used to accelerate the breeding process by predicting the performance of different genetic combinations under varying climatic conditions. This approach helps in the development of crop varieties that are better adapted to the changing climate.
5. **Capacity building and knowledge sharing:** To promote the adoption of AI and remote sensing technologies in agriculture, various capacity building initiatives and knowledge sharing platforms have been established in India. Government agencies, research institutions, and non-profit organizations conduct training programs, workshops, and webinars to educate farmers, extension workers, and policymakers about the benefits and applications of these technologies. Additionally, online portals and mobile applications provide access to weather forecasts, crop advisories, and satellite-based information services, empowering farmers to make data-driven decisions for climate-resilient agriculture.

Overall, India's innovation in AI and remote sensing for climate-resilient agriculture holds great promise for improving the livelihoods of farmers, enhancing food security, and building resilience to climate change impacts. Continued investment in research, technology development, and capacity building is essential to harness the full potential of these technologies for sustainable agricultural development

Conclusion:

The integration of artificial intelligence and remote sensing techniques holds immense promise for advancing climate-resilient agriculture and addressing the complex challenges of food security, environmental sustainability, and climate change. By harnessing the power of data-driven insights, predictive analytics, and decision support tools, policymakers, researchers, and agricultural stakeholders can develop innovative solutions, promote adaptive management practices, and build resilient food systems capable of withstanding the impacts of climate variability and extremes. However, realizing the full potential of AI and remote sensing in agriculture requires concerted efforts to address data governance, technical capacity building, and ethical considerations, ensuring that technology-driven innovations benefit farmers, communities, and ecosystems alike. Through collaborative partnerships, innovation ecosystems, and inclusive policies, we can harness the promise of AI and remote sensing to create a more sustainable, equitable, and resilient future for agriculture and food production.

References:

1. Jain, V., Kumar, A., & Singh, S. P. (2019). Application of remote sensing and GIS in climate change monitoring and sustainable agriculture: A review. International Journal of Applied Earth Observation and Geoinformation, 79, 55-64.
2. Bhatt, L. P., Pandey, S., & Ghosh, S. K. (2017). Using Artificial Intelligence and Remote Sensing Technologies for Sustainable Agriculture: A Review. Journal of Applied Remote Sensing, 11(4), 042609.
3. Sikka, A., Jat, M. L., & Saharawat, Y. S. (2019). Climate-smart agriculture: perspectives and constraints in the Indo-Gangetic Plains. Current Science, 116(1), 29-35.
4. Ilangakoon, G. R., Jayawardena, T. G., & Gunawardena, U. A. D. P. (2020). Remote Sensing-Based Assessment of Climate Change Impacts on Agriculture: A Review. Journal of the National Science Foundation of Sri Lanka, 48(1), 1-14.
5. Gupta, D., Kulshreshtha, A., & Mishra, S. N. (2019). Artificial Intelligence in Agriculture: A Review. International Journal of Current Microbiology and Applied Sciences, 8(10), 1927-1934.
6. Sharma, P., & Sharma, R. (2019). Use of artificial intelligence for crop yield prediction: A review. International Journal of Computer Applications, 182(23), 6-11.
7. Lobell, D. B., & Burke, M. B. (2010). On the use of statistical models to predict crop yield responses to climate change. Agricultural and Forest Meteorology, 150(11), 1443-1452.
8. Rodriguez, D., & Bock, A. (2017). Using remote sensing for crop yield prediction: An overview. Computers and Electronics in Agriculture, 138, 11-26.
9. Kandasamy, M., Kathirvel, K., & Pathirana, S. (2019). Agriculture crop yield prediction using machine learning techniques: A comprehensive review. Computers and Electronics in Agriculture, 162, 219-236.
10. Mishra, A. R., & Lal, R. (2017). Soil health restoration and management for climate-resilient agriculture: A review. Land Degradation & Development, 28(1), 17-40.

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