ICAAAS
An Edited Book

Volume-2

Chief Editor : Dr. S.P. Singh

Compiled & Edited for

Astha Foundation, Meerut (U.P.) INDIA

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Innovative and Current Advances in Agriculture & Allied Sciences

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Volume-2

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From Chief Editor's Desk

ICAAAS : An Initiative towards Sustainable Agriculture & Allied Sciences

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About ICAAAS

Innovative and Current Advances in Agriculture and Allied Sciences (ICAAAS), a brain child of **Astha Foundation** to bring scientists, researchers, academicians and all stake holders from throughout the globe for the betterment of humanity with the involvement of all the branches of sciences and related field is organizing the conferences. The five different themes of sessions were planned for the ICAAAS and these themes itself explains the vision of ICAAAS are :

1. Innovation in Crop Improvement, Biotechnology, Genetic Engineering, Precision Horticulture, Agroforestry and Impact of Climate Change on Biodiversity and Food Security.
2. Advances in Disease and Pest Management, Livelihood and Sustainable Management Practices, Post-Harvest Technology, Food Processing and Value Addition for Augmenting Farmer's Income.
3. Key Factor for Crop Productivity: Cropping System, Agronomic and Soil Health Management Practices, Farm Mechanization, Indigenous Technical Knowledge and IPR Issues.
4. Recent Advances in Animal Health, Animal Nutrition & Husbandry, Dairy, Poultry and Fisheries Technology.
5. New Frontiers in Physical, Chemical, Mathematical, Biological, Social Sciences, Remote Sensing, Smart Agriculture, Information Technology, Digital Library and Huminities.

The **first ICAAAS** conference was organized during 10-11th December, 2016 at Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad (Telangana). It received overwhelming response with the registration of more than **800** participants. The **second ICAAAS** International Conference was organized during 27 January to 01 February, 2020 at Bangkok, Thailand. with more than **100** registrations in the conference. The **third ICAAAS** International Conference was organized during 19-21st July, 2021 from the headquarter of Society for Scientific Development in Agriculture and Technology (SSDAT) at Meerut considering the post pandemic effect and travel restrictions. In spite of corona pandemic it received overwhelming response with **1043** Participants. The **fourth ICAAAS** International Conference, was organized in hybrid mode at the campus of Himachal Pradesh University, Shimla during 12-14th June, 2022. This time more than **1200** participations with 250 offline participation is expected including some foreign experts. The **fifth ICAAAS** International Conference, was organized in hybrid mode at Hotel Howard Johnson by Wyndham Bur Dubai Khalid Bin Al Waleed Rd-Al Raffa-Dubai, UAE. This time more than **500** participations with 85 offline participation is expected including some foreign experts.

Thus the society is serving the scientific and farming community through sharing a common

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platform with the publication of literature on recommendations based on the conferences organized and problem solving of the stake holders.

ICAAAS : The beginning

Worldwide demands for food increases (population of over 8 billion by 2025) while land and water become increasingly scarce and human health issues rise and threaten food systems and their sustainability. There will be no sustainable future without eradicating poverty and hunger. Ensuring food security for all is both a key function and a challenge for agriculture, which faces ever-increasing difficulties–as populations and urbanization. The agricultural sector will be under mounting pressure to meet the demand for safe and nutritious food. Agriculture has to generate decent jobs and support the livelihoods of billions of rural people across the globe, especially in developing countries where hunger and poverty are concentrated. Furthermore, the sector has a major role to play in ensuring the sustainability of the world's precious natural resources and biodiversity, particularly in light of a changing climate. Climate change will have an increasingly adverse impact on many regions of the world, with those in low latitudes being hit the hardest. Developing countries, in particular, will need support from the global community to facilitate their adaptation and mitigation efforts in relation to climate change and to transform their agriculture and food systems sustainably. As the migration crisis of recent years has shown, no country stands unaffected. What happens in one part of the globe will undoubtedly affect other parts, and domestic and foreign policies must take account of this.

Global Agriculture Research institutes

At global level only mandated international agricultural research organization is the CGIAR. The CGIAR Fund supports 15 international agricultural research centers such as the International Water Management Institute (IWMI), International Rice Research Institute (IRRI), the International Institute of Tropical Agriculture (IITA), the International Livestock Research Institute (ILRI), the International Food Policy Research (IFPRI) and the Center for International Forestry Research (CIFOR) that form the CGIAR Consortium of International Agricultural Research Centers and are located in various countries worldwide (as of 2011), The centers carry out research on various agricultural commodities, livestock, fish, water, forestry, policy and management. Some other international agricultural organizations include the United Nations Food and Agriculture Organization, Global Forum on Agricultural Research (GFAR), The International Agriculture Center (Netherlands), The World Bank, International Fund for Agricultural Development, The Center for International Food and Agriculture Policy at the University of Minnesota. The CGIAR (Consultative Group on International Agricultural Research) is a small but significant component of the global agricultural research system. With its limited financial resources, it has to be selective in its role and choice of research portfolio. An updated report on CGIAR priorities and strategies is produced every five years by TAC (Technical Advisory Committee to the CGIAR) to guide system-wide resource allocation taking into consideration an appropriate balance between centers, activities, commodities, regions and agro-ecological zones. In considering priorities, TAC is guided by several important factors such as the CGIAR mission and goal, emerging trends in world agriculture, and the evolution of scientific capacity in developing countries. The current approach has been modified to account for the expanded mandate of the CGIAR, greater emphasis on sustain-ability and resource management issues, allow for meaningful interactions with stakeholders, ensure transparency in decision making, and develop mechanisms which facilitate CGIAR priority setting as a continuing activity.

What is Sustainable Agriculture : Every day, farmers and ranchers around the world develop new, innovative strategies to produce and distribute food, fuel and fiber sustainably. While these strategies vary greatly, they all embrace three broad goals, or what SARE calls the 3 Pillars of Sustainability: Profit over the long term, Stewardship of nation's land, air and water and Quality of life for farmers, ranchers and their communities. The phrase 'sustainable agriculture' was reportedly coined by the Australian agricultural scientist Gordon McClymont Wes Jackson is credited with the first publication of the expression in his 1980 book *New Roots for Agriculture*. The term became popular in the late 1980s. It has been defined as "an integrated system of plant and animal production practices having a site-specific application that will last over the long term, for example to satisfy human food and fiber needs, to enhance environmental quality and the natural resource base upon which the agricultural economy depends, to make the most efficient use of non-renewable and on-farm resources and integrate natural biological cycles and controls, to sustain the economic viability of farm operations, and to enhance the quality of life for farmers and society as a whole.

There are several key principles associated with sustainability in agriculture.

The incorporation of biological and ecological processes into agricultural and food production practices. For example, these processes could include nutrient cycling, soil regeneration, and nitrogen fixation.

Using decreased amounts of non-renewable and unsustainable inputs, particularly the ones that are environmentally harmful.

Using the expertise of farmers to both productively work the land as well as to promote the self-reliance and self-sufficiency of farmers.

Solving agricultural and natural resource problems through the cooperation and collaboration of people with different skills. The problems tackled include pest management and irrigation.

Sustainable agriculture can be understood as an ecosystem approach to agriculture. Practices that can cause long-term damage to soil include excessive tilling of the soil (leading to erosion) and irrigation without adequate drainage (leading to salinization). Long-term experiments have provided some of the best data on how various practices affect soil properties essential to sustainability. In the United States a federal agency, USDA-Natural Resources Conservation Service, specializes in providing technical and financial assistance for those interested in pursuing natural resource conservation and production agriculture as compatible goals.

Initiatives by United Nations for sustainable development

The year 2015 signalled the arrival of two landmark initiatives that recognized the need for countries to take collective action to promote sustainable development and combat climate change: the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs), and the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC). Both initiatives reflect evolving thinking around global issues, and both call for a fair and transparent international trade system. In food and agriculture, trade can play a role and contribute to meeting the targets of both the 2030 Agenda and the Paris Agreement.

In the meeting at the United Nations Headquarters in New York from 25-27 September 2015 as the Organization celebrated its seventieth anniversary, have decided on new global Sustainable Development Goals. UN adopted a historic decision on a comprehensive, far-reaching and people-centred set of universal and transformative Goals and targets and committed to working tirelessly for the full implementation of this Agenda by 2030.

The sustainable development goals : The sustainable development goals (SDGs) are a new, universal set of goals, targets and indicators that UN member states will be expected to use to frame their agendas and political policies over the next 15 years. The SDGs follow and expand on the millennium development goals (MDGs), which were agreed by governments in 2001 and are due to expire at the end of this year.

Need for set of goals : There is broad agreement that, while the MDGs provided a focal point for governments– a framework around which they could develop policies and overseas aid programmes designed to end poverty and improve the lives of poor people – as well as a rallying point for NGOs to hold them to account, they were too narrow.

The eight MDGs: reduce poverty and hunger; achieve universal education; promote gender equality; reduce child and maternal deaths; combat HIV, malaria and other diseases; ensure environmental sustainability; develop global partnerships – failed to consider the root causes of poverty and overlooked gender inequality as well as the holistic nature of development. The goals made no mention of human rights and did not specifically address economic development. While the MDGs, in theory, applied to all countries, in reality they were considered targets for poor countries to achieve, with finance from wealthy states. Conversely, every country will be expected to work towards achieving the SDGs.

Proposed 17 Sustainable Development Goals (SDGs)

End poverty in all its forms everywhere

End hunger, achieve food security and improved nutrition, and promote sustainable agriculture

Ensure healthy lives and promote wellbeing for all at all ages

Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Achieve gender equality and empower all women and girls

Ensure availability and sustainable management of water and sanitation for all

Ensure access to affordable, reliable, sustainable and modern energy for all

Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all

Build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation

Reduce inequality within and among countries

Make cities and human settlements inclusive, safe, resilient and sustainable

Ensure sustainable consumption and production patterns

Take urgent action to combat climate change and its impacts (taking note of agreements made by the UNFCCC forum)

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation, and halt biodiversity loss

Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Strengthen the means of implementation and revitalise the global partnership for sustainable development

Within the goals are 169 targets, to put a bit of meat on the bones. Targets under goal one, for example, include reducing by at least half the number of people living in poverty by 2030, and eradicating extreme poverty (people living on less than $1.25 a day). Under goal five, there's a target on eliminating violence against women, while goal 16 has a target to promote the rule of law and equal access to justice.

The Global Research Alliance (GRA) : Is an international network of nine applied research organizations that works to promote application of science and technology to solve large scale issues facing developing countries. The alliance was formed in 2000 in Pretoria, South Africa. Today, the GRA has access to over 60,000 people across its membership. Vision is for a world where the application of innovative science and technology, through collaboration and co-creation, delivers access equality, improves lives, and solves global development challenges.The GRA uses the best science and technology to solve some of the biggest problems in the developing world. These global issues span borders, cultures and religions and require a cross-boundary response. They address these problems by :

Mobilising the creative energy of our globally and culturally diverse researchers to address global development challenges through innovation

Saring the breadth and depth of our science and technology resources and uniting with local partners, communities, industry and collaborators

Generating and implementing appropriate, affordable and sustainable solutions with positive and lasting impact

The GRA is a dynamic alliance of nine knowledge intensive research and technology organizations from around the world. Its goal is to create 'A Global Knowledge Pool for Global Good'. The focus is to apply science, technology and innovation in the pursuit of solving some of world's gravest challenges.

GRA and Inclusive Innovation : The Global Research Alliance (GRA) believes Inclusive Innovation requires a holistic and new way of approaching demand-driven projects and co-creation with partners such as end-users, technology organizations and both the private and public sectors. This includes: success through technical innovation (products), social innovation (interaction/co-creation), management innovation (business models); and chain innovation (relationships in the value chain). Inclusive Innovation is not new to the GRA. Over the last few years, the GRA has systematically addressed global challenges through the deployment of Inclusive Innovation initiatives.

Why do we need climate-smart agriculture : The UN Food and Agriculture Organization (FAO) estimates that feeding the world population will require a 60 percent increase in total agricultural production. With many of the resources needed for sustainable food security already stretched, the food security challenges are huge. At the same time climate change is already negatively impacting agricultural production globally and locally. Climate risks to cropping, livestock and fisheries are expected to increase in coming decades, particularly in low-income countries where adaptive capacity is weaker. Impacts on agriculture threaten both food security and agriculture's pivotal role in rural livelihoods and broad-based development. Also the agricultural sector, if emissions from land use change are also included, generates about one-quarter of global greenhouse gas emissions.

Practical adaptation options to improve food security and resilience : What practical steps can smallholder farmers take to adapt their agricultural practices to secure dependable food supplies and livelihoods? And can they do this while also decreasing greenhouse gas emissions or increasing carbon sequestration, thereby decreasing future climate change?

The Global Water Partnership's : vision is for a water secure world. Its mission is to support the sustainable development and management of water resources at all levels GWP was founded in 1996 by the World Bank, the United Nations Development Programme (UNDP), and the Swedish International Development Cooperation Agency (SIDA) to foster integrated water resource management (IWRM).

IWRM is a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare without compromising the sustainability of ecosystems and the environment. The network is open to all organisations involved in water resources management : developed and developing country government institutions, agencies of the United Nations, bi- and multi-lateral development banks, professional associations, research institutions, non-governmental organisations, and the private sector. In the "Our Approach" section one can read about GWP's global strategy - Towards 2020 - how GWP are currently pursuing vision of water security. Dealing with water issues requires commitment at the highest political level. Water security will only be reached when political leaders take the lead, make the tough decisions about the different uses of water and follow through with financing and implementation. GWP sees its role as having the technical expertise and convening power to bring together diverse stakeholders who can contribute to the social and political change processes that help bring the vision of a water secure world closer to reality. GWP regularly reports on outcomes at the national, regional, and global level. GWP is implementing its strategy and up-to-date information on activities across the globe.

The Global Water Partnership (GWP) has announced the launch of its new 2014-2019 global strategy. The strategy, Towards 2020, outlines a new direction for GWP with the goals of catalyzing change, sharing knowledge, and

Strengthening partnerships for a water secure world : The 2014-2019 Strategy builds on GWP's previous work and achievements. It was developed through a year-long process of regional dialogues and consultations with GWP's growing network of over 2,900 Partner Organizations across 172 countries. "The strategy Towards 2020 stresses the need for innovative and multi-sectoral approaches to adequately address the manifold threats and opportunities relating to sustainable water resource management in the context of climate change, rapid urbanization, and growing inequalities," Knowledge generation and communication continues to be a central part of GWP's work with this strategy. "Knowledge and new tools are needed to support policy development and decision making and enable the effective and sustainable management of water resources," "Knowledge can stimulate behavioural change towards a new 'water culture'. New to this strategy is a thematic approach in six key areas of development–climate change, transboundary cooperation, food, urbanisation, energy, and ecosystems. "Integrated water management is fundamental to all of these areas of the global development agenda. Our new thematic approach will ensure the crucial link to water security is made across these thematic focus areas for meeting sustainable development goals," explains GWP Executive Secretary Dr Ania Grobicki.

The global launch of the strategy took place at the Official United Nations World Water Day celebrations in Tokyo, Japan, on 21 March 2014.

Global Soil Partnership : Soil is under pressure. The renewed recognition of the central role of soil resources as a basis for food security and their provision of key ecosystem services, including climate change adaptation and mitigation, has triggered numerous regional and international projects, initiatives and actions. Despite these numerous emergent activities, soil resources are still seen as a second-tier priority and no international governance body exists that advocates for and coordinates initiatives to ensure that knowledge and recognition of soils are appropriately represented in global change dialogues and decision making processes. At the same time, there is need for coordination and partnership to create a unified and recognized voice for soils and to avoid fragmentation of efforts and wastage of resources.

Maintaining healthy soils required for feeding the growing population of the world and meeting their needs for biomass (energy), fiber, fodder, and other products can only be ensured through a strong partnership. This is one of the key guiding principles for the establishment of the Global Soil Partnership.

Responses to soils today

Soil data : fragmented, partly outdated (fertility, SOC, etc.) heterogeneous and difficult to compare, not easily accessible, not responding to users needs

Soil capacities : increasingly a scarce resources (loss of soil expertise and skills)

Soil knowledge and research : fragmented (fertility, CC, ecology), domain of soil scientists, not accessible for use by various disciplines and for decision making, not tailored to address problems/ development agendas of today

Awareness and investments in soil management : extremely low compared to the needs that soil is a precarious resource and requires special care from its users.

Soil policy : Often received as a second tier priority; lack of international governance body to support coordinated global action on their management.

Need for compatible and coordinated soil policies : a unified and authoritative voice is needed to better coordinate efforts and pool limited resources (for agriculture, forestry, food security, UNCCD, CBD, UNFCCC, disaster and drought management, land competition, rural and urban land use planning and development).

Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. In the same year, the UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC. The IPCC is a scientific body under the auspices of the United Nations (UN). It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters. Thousands of scientists from all over the world contribute to the work of the IPCC on a voluntary basis. Review is an essential part of the IPCC process, to ensure an objective and complete assessment of current information. IPCC aims to reflect a range of views and expertise. The Secretariat coordinates all the IPCC work and liaises with Governments. It is established by WMO and UNEP and located at WMO headquarters in Geneva. Because of its scientific and intergovernmental nature, the IPCC embodies a unique opportunity to provide rigorous and balanced scientific information to decision makers. By endorsing the IPCC reports, governments acknowledge.

The Intergovernmental Technical Panel on Soils (ITPS) was established at the first Plenary Assembly of the Global

Soil Partnership held at FAO Headquarters on 11 and 12 of June, 2013. The ITPS is composed of 27 top soil experts representing all the regions of the world. The main function of the ITPS is to provide scientific and technical advice and guidance on global soil issues to the Global Soil Partnership primarily and to specific requests submitted by global or regional institutions. The ITPS will advocate for addressing sustainable soil management in the different sustainable development agendas.

Functions of ITPS : The ITPS have the following functions :

provide scientific and technical advice on global soil issues primarily to the GSP and in relation to specific requests submitted by global or regional institutions.

advocate for the inclusion of sustainable soil management into different development agendas.

review and follow up on the situation and issues related to soils in the contexts of food security, use and management of natural resources, ecosystem services provision, climate change adaptation and mitigation, and other relevant areas.

review and endorse from a technical viewpoint the GSP Plans of Action.

Follow up on the implementation of these Plans of Action with due attention to their impact and contributions to different global policies and initiatives related to sustainable development, MDGs, food security, climate change adaptation and other subject matters.

in exceptional cases, when complex technical matters arise, request the Plenary Assembly and the Secretariat to form technical committees aiming to gather specific advice.

Intergovernmental Platform on Biodiversity and Ecosystem Services : The Intergovernmental Platform on Biodiversity and Ecosystem Services is a mechanism proposed to further strengthen the science-policy interface on biodiversity and ecosystem services, and add to the contribution of existing processes that aim at ensuring that decisions are made on the basis of the best available scientific information on conservation and sustainable use of biodiversity and ecosystem services. It was established in 2012 as an independent intergovernmental body open to all member countries of the United Nations. The members are committed to building IPBES as the leading intergovernmental body for assessing the state of the planet's biodiversity, its ecosystems and the essential services they provide to society.

What is the science-policy interface : Science-policy interfaces are social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making at different scales. This includes 2 main requirements :

that scientific information is relevant to policy demands and is formulated in a way that is accessible to policy and decision makers; and

that policy and decision makers take into account available scientific information in their deliberations and that they formulate their demands or questions in a way that are accessible for scientists to provide the relevant information.

Need for IPBES : There are already several mechanisms and processes at national, regional and global level that are designed to ensure that scientific information is considered when designing policies or making decisions (examples of this are technical bodies/panels under the environmental agreements or national research institutions attached to ministries, among many others). However, there is no global ongoing mechanism recognized by the scientific and policy communities, that pulls this information together, synthesizes and analyzes it for decision making in a range of policy fora.

We have listed some of the numerous global alliances which have been established to address the global research platforms. This is in brief and there are others also across the globe taking shapes : One of the fundamental lessons learned through the past half century of agricultural research is that there are no "one size fits all" sustainable management practices and a holistic approach is the need of the hour.

Sustainable development in Indian Agriculture

Agriculture is the main occupation in India as large population is living in the rural areas and having agriculture as their livelihood. Sustainable development in the agriculture sector aims to increase the productivity, efficiency and level of employment and further aims to protect and preserve the natural resources by the over utilization. Agriculture faces many challenges, making it more and more difficult to achieve its primary objective – feeding the world – each year. Agriculture must change to meet the rising demand, to contribute more effectively to the reduction of poverty and malnutrition, and to become ecologically more sustainable India has been witnessing a blinding pace of growth and development in recent times. Experts are now calling for "sustainable development" and the term has gained currency in the last few years. In spite of fast growth in various sectors, agriculture remains the backbone of the Indian economy. Sustainable agricultural development seeks not only to preserve and maintain natural resources, but also to develop them, as future generations would have much more demand quantity-wise and quality-wise for agricultural and food products. Such goals should ensure a balance with the development of livelihoods enjoyed by the individuals concerned. Agriculture plays a crucial role in sustainable development and in hunger and poverty eradication. The challenges faced by agriculture in sustainable development is in working out ways of bringing about a society that is materially sufficient, socially equitable, and ecologically sustainable and one that is not obsessed by growth only, but motivated by satisfying human needs and equity in resource allocation and use. Sustainable agriculture must meet economic, social and ecological challenges. All 4 these challenges are closely related. Sustainable agriculture needs to protect the natural resource base, prevent the degradation of soil and water; conserve biodiversity; contribute to the economic and social well-being of all; ensure a safe and high-quality supply of agricultural products; and safeguard the livelihood and well-being of agricultural workers and their families. The main tools towards sustainable agriculture are policy and agrarian reform, participation, income diversification, land conservation and improved management of inputs. This policy document is an effort to identify the strategies, guidelines and practices that constitute the Indian concept of sustainable agriculture. This is done in order to clarify the research agenda and priorities thereof, as well as to suggest practical steps that may be appropriate for moving towards sustainable agriculture. Some tend to confuse sustainable agriculture with organic farming. But both are very different form each other. Sustainable agriculture means not only the withdrawal of synthetic chemicals, hybrid-genetically modified seeds and heavy agricultural implements (as in organic farming). Sustainable agriculture involves multiculture, intercropping, use of farmyard manure and remnants, mulching and application of integrated pest management. If this is followed then there is no reason why agriculture cannot be an economically viable activity in addition to being environmentally sustainable.

In India, the crop yield is heavily dependent on rain, which is the main reason for the declining growth rate of agriculture sector. These uncertainties hit the small farmers and laborers worst, which are usually leading a hand to mouth life. Therefore, something must be done to support farmers and sufficient amount of water and electricity must be supplied to them as they feel insecure and continue to die of drought, flood, and fire. India is the second largest country of the world in terms of population; it should realize it is a great resource for the country. India has a huge number of idle people. There is a need to find ways to explore their talent and make the numbers contribute towards the growth. Especially in agriculture, passive unemployment can be noticed. The sustainable development in India can also be achieved by full utilization of human resources .A large part of poor population of the country is engaged in agriculture, unless we increase their living standard, overall growth of this country is not possible. If we keep ignoring the poor, this disparity will keep on increasing between classes. Debt traps in country are forcing farmers to commit suicides. People are migrating towards city with the hope of better livelihood but it is also increasing the slum population in cities. Therefore, rural population must be given employment in their areas and a chance to prosper. India has been carrying the tag of "developing" country for quite long now; for making the move towards "developed" countries, we must shed this huge dependence on agriculture sector.

For promoting sustainable agriculture, following components can be considered :

Yield increase : India need to focus on improving its yields. Currently, yield level of food crops is 2,056 kg/ha, which is far below the yields of many countries. The current average yield of paddy in India is around 3.5 tonnes/ha, while China's yield is more than 6 tonnes/ha. Similar is the case with wheat and other major crops. This is despite increase in fertilizers and pesticides by several folds.

Water-use efficiency : India is still focusing on supply side management of water. This is leading to major investments while causing degradation of ecosystems without any major benefit to farmers. The investments have to be clearly on reducing the water per unit of production. Currently, the focus of drip irrigation is only on material supply rather than the entire process and training. Creating specific incentives for using less water while improving the productivity have not even initiated. With modern technology, it is possible to create incentives to use less water and set up mechanisms to monitor water use at farm level. Budget should be allocated for creating well-designed projects with institutional mechanisms to implement and monitor. The goal is to use the existing infrastructure far more efficiently—both at system level and individual farm level.

Diversity of food grains : Consumers are aware of the benefits of eating coarse grains such as jowar and bajra. But there are no specific programmes to produce and market these food grains. Farmers need income, not just production. So, incentivising farmers to produce these grains will not only save water and ecosystems but promote healthy eating habits.

Farm-based approaches : In India, farmers are receptive to experimenting with farm-based approaches. For example, the System of Rice Intensification (SRI), Sustainable Sugarcane Initiative (SSI), and System of Crop Intensification (SCI) of wheat, millets and mustard are very popular with farmers. It is time we had Centre-sponsored scheme to promote these approaches in large scale with large budget provisions and institutional mechanisms.

Organic agriculture : India needs to slowly move from chemical-based farming to organic farming. Phase-wise approach towards removing subsidies to chemical fertilizers and introducing incentives to organic agriculture through budget provisions is the way to go about it.

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Chapter 1

Biofortification of Pulses : Enhancing Nutritional Value and Addressing Global Health Challenges

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Abstract

This chapter discusses pulse crop biofortification and nutritional shortages. Biofortification's role in nutritional deficiency is explained in the chapter's introduction. It summarizes the chapter. To comprehend pulse crops, the chapter describes and analyzes their nutritional content. It also covers pulse crop production issues. The chapter discusses dietary deficits and their effects on public health. Biofortification is crucial to addressing these inadequacies. Biofortification is explained, covering agronomic, genetic, and breeding procedures. Biofortification initiatives and their results demonstrate their efficacy. Explore pulse biofortification potential and nutritional objectives. Seed priming, micronutrient foliar treatments, and pulse crop breeding are explored. Bio fortified pulses' bioavailability and health advantages are explored. Bio fortified pulses improve nutrition and health, according to case studies and research. The chapter explores pulse biofortification difficulties and solutions. Educating farmers, consumers, and politicians about bio fortified pulses is discussed. Bio enriched pulse projects that benefit communities are shown. Future trends and pulse crop biofortification technologies complete the chapter. It suggests expanding biofortification to more people. Bio fortified pulses can improve public health and solve nutritional inadequacies.

Introduction

a. Definition and Explanation of Biofortification

A sustainable and economical agricultural method called biofortification aims to enhance the nutritional value of crops by boosting their concentration of vital vitamins and minerals. To fight micronutrient deficits, sometimes known as "hidden hunger," it entails breeding or selecting foods with increased vitamin content. To improve the nutritional content of basic food crops like pulses, this procedure uses traditional breeding methods or genetic engineering techniques. Specific minerals that are important for human health, such as iron, zinc, vitamins A, C, and folate, can be targeted through biofortification. Biofortification provides a long-term and sustainable solution to nutritional shortages, especially in resource-restricted countries where access to a variety of nutrient-dense meals is curtailed. A sustainable and economical agricultural method called biofortification aims to enhance the nutritional value of crops by boosting their concentration of vital vitamins and minerals. To fight micronutrient deficits, sometimes known as "hidden hunger," it entails breeding or selecting foods with increased vitamin content. To improve the nutritional content of basic food crops like pulses, this procedure uses traditional breeding methods or genetic engineering techniques. Specific minerals that are

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important for human health, such as iron, zinc, vitamins A, C, and folate, can be targeted through biofortification. Biofortification provides a long-term and sustainable solution to nutritional shortages, especially in resource-restricted countries where access to a variety of nutrient-dense meals is curtailed.

b. Significance of Biofortification in Addressing Nutrient Deficiencies

Throughout the world, especially in underdeveloped nations, millions of people suffer from micronutrient deficiencies, or hidden hunger. Lack of important vitamins and minerals in the diet can have negative effects on health, such as weakened immune systems, stunted growth and development, increased susceptibility to illnesses, and even greater death rates, particularly in children and pregnant women. The expense, logistical, and accessibility issues with traditional techniques of addressing nutritional deficiencies, such as supplementation and fortification, is significant. By incorporating nutritional improvements directly into the food crops that people consume on a daily basis, biofortification presents a possible option. Biofortification has the ability to reach disadvantaged communities and provide a sustainable and continuous supply of essential nutrients by enhancing the nutritional content of staple crops like pulses.

c. Overview of the Chapter's Content

In order to address nutritional shortages and advance improved health outcomes, this chapter attempts to give a thorough grasp of the significance of biofortification, especially in pulses. This is how the chapter will be organized:

Introduction : The concept and importance of biofortification in correcting nutritional shortages are highlighted in this part, which gives a synopsis of the chapter's material.

Understanding Pulse Crops: This section examines the description and traits of pulse crops, focusing on their use as a main source of food and the nutrients they contain.

Nutritional Deficiencies and Public Health Implications: This chapter examines the widespread nutritional deficiencies that affect people's health. The importance of biofortification as a strategy to address these shortcomings is highlighted in this section.

Concepts and procedures for biofortification: This section describes the idea behind biofortification and the numerous strategies used, including breeding, genetic, and agronomic procedures. Additionally, examples of effective biofortification projects and their results are shown.

This section examines the biofortification potential of pulses by concentrating on certain particular crops. It goes through the nutritional goals for pulse biofortification and provides a rundown of the specific methods employed.

Understanding Pulse Crops

a. Definition and Examples of Pulse Crops

Pulse crops, commonly referred to as grain legumes, are a class of plants in the Fabaceae family. They may be identified by the dry, edible seeds that are encased in a pod. The worldwide use of pulses makes them a vital source of plant-based protein. Pulse crops include things like chickpeas, lentils, dry beans, dry peas, and soybeans, to name a few. In many different ethnic and culinary traditions, pulses have been grown for ages. Due to their capacity to flourish in a variety of agro-ecological settings and contribute to sustainable agricultural systems, they play a crucial role in ensuring the safety of the world's food supply. Since pulse crops fix nitrogen in the soil, enhancing soil fertility and lowering the demand for synthetic fertilizers, they are especially advantageous in crop rotation systems.

b. Nutritional Composition of Pulses

Pulses are crops that are rich in nutrients and provide a variety of crucial nutrients. They are a great source of plant-based protein, complex carbs, dietary fiber, and a variety of vitamins and minerals. Although the nutritional makeup of different varieties of pulses may differ significantly, they often have the following important qualities in common:

Pulses are a significant source of protein, particularly in vegetarian and vegan diets, due to their high protein content. Pulses generally contain 20% to 30% protein, which puts them on par with meat and dairy products in terms of protein content. Complex carbohydrates, such as starches and dietary fiber, are present in pulses. Pulses often include a lot of fiber, which helps with better blood sugar regulation, cholesterol reduction, and improved digestion. Pulses are a good source of a number of micronutrients, including folate, iron, zinc, magnesium, and B vitamins. These nutrients are essential for red blood cell synthesis, immune system health, energy metabolism, and general health. Pulses are abundant in Phytochemicals, such as flavonoids and phenolic compounds, which have anti-inflammatory and antioxidant characteristics. The possible health advantages of consuming pulses are influenced by these substances.

c. Common Challenges and Limitations in Pulse Crop Production

While pulse crops offer numerous benefits, their production faces several challenges and limitations:

Environmental Stress: Drought, heat, and insect infestations are only a few examples of the environmental stressors that can affect pulse crops. Pulse crop production is significantly threatened by climate change because changes in temperature and rainfall patterns can affect crop yields and quality.

Disease and Pest Pressure: Pulses are susceptible to a number of illnesses, including viral and fungal infections, as well as insect infestations, including beetle and aphid problems. It is essential to use efficient pest and disease management techniques to ensure healthy pulse crops.

Genetic Diversity: Pulse crop cultivars with low genetic diversity may be more susceptible to diseases and pests. Breeding initiatives that increase genetic diversity are crucial for creating hardy pulse types.

Market Access and Demand: Despite their nutritional advantages, pulses frequently encounter problems with market access and customer demand. These obstacles may be surmounted by promoting pulse consumption and developing market possibilities.

Post-harvest treatment: maintaining pulse quality and minimizing losses depend on proper post-harvest treatment. It is necessary to deal with problems such as storage pests, seed damage, and quality degradation during storage and transit.

Nutritional Deficiencies and Public Health Implications

a. Explanation of Common Nutrient Deficiencies Prevalent Worldwide

Micronutrient deficiencies, commonly referred to as hidden hunger or nutrient deficiencies, refer to low intakes or levels of vital vitamins and minerals in the diet. Billions of individuals of all ages worldwide, particularly in underdeveloped nations, are impacted by these inadequacies. Numerous nutritional deficits are widespread across the world, including:

Iron Deficiency: Iron deficiency is the most widespread nutrient deficiency globally. It can lead to iron-deficiency anemia, resulting in fatigue, impaired cognitive function, compromised immune response, and increased susceptibility to infections.

Zinc Deficiency: Zinc deficiency is prevalent, especially in low- and middle-income countries. It can cause growth retardation, impaired immune function, increased risk of infectious diseases, and delayed wound healing.

Vitamin A Deficiency: Vitamin A deficiency is a significant public health problem in many developing countries. It can lead to visual impairments, compromised immune function, increased susceptibility to infections, and even blindness, particularly in children.

Iodine Deficiency: Iodine deficiency affects a large population globally, primarily in areas where iodized salt is not widely available. It can result in goiter, impaired brain development, cognitive impairments, and increased risk of stillbirths and infant mortality.

Vitamin D Deficiency: Vitamin D deficiency is prevalent worldwide, affecting both developed and developing countries. It can lead to impaired bone health, increased risk of fractures, weakened immune function, and an association with various chronic diseases.

b. Impact of Nutrient Deficiencies on Human Health and Well-being

Human health and wellbeing are significantly impacted by nutrient deficits. Depending on the particular nutritional shortage, as well as its severity and length, different outcomes may result. Several frequent effects include:

Impaired Growth and Development: Nutrient deficiencies can lead to stunted growth, delayed development, and reduced cognitive function in children. This can have long-term consequences on educational attainment, productivity, and economic well-being.

Compromised Immune Function: Many nutrient deficiencies weaken the immune system, making individuals more susceptible to infections and diseases. This can result in increased morbidity and mortality rates, particularly among children and vulnerable populations.

Increased Risk of Chronic Diseases: Nutrient deficiencies have been linked to an increased risk of chronic diseases, such as cardiovascular diseases, diabetes, and certain types of cancer. For example, low levels of antioxidants like vitamin C and vitamin E can contribute to oxidative stress and chronic inflammation.

Maternal and Child Health Risks: Nutrient deficiencies during pregnancy can have adverse effects on both the mother and the developing fetus. They can increase the risk of preterm birth, low birth weight, birth defects, and maternal complications.

Impaired Cognitive Function: Nutrient deficiencies, particularly during critical periods of growth and development, can impair cognitive function, learning abilities, and overall mental well-being. This can have long-term consequences on educational achievement and socio-economic outcomes

c. Importance of Addressing Nutrient Deficiencies through Biofortification

For the sake of enhancing public health and wellbeing, particularly in areas with limited resources, nutritional deficiencies must be addressed. A sustainable and economical solution to address these deficits is biofortification. Here are some reasons biofortification is crucial:

Targeted Nutrient Enhancement: The targeted improvement of particular nutrients in staple food crops is made possible by biofortification. Biofortification enables the distribution of important vitamins and minerals to large populations by enhancing the nutritional value of frequently eaten crops like pulses.

Integration into Local Food Systems: Bio fortified crops may be included into regional food systems, ensuring that populations have access to and can afford nutrient-dense diets. This strategy encourages dietary variety and lessens the need for pricey dietary supplements or fortification initiatives.

Long-Term Impact: By introducing increased nutritional content directly into the crops, biofortification offers a long-term remedy to nutrient inadequacies. This guarantees that the nutritional advantages endure over time, especially in regions with poor access to medical care or dietary modifications.

Cost-Effectiveness: Biofortification is a more affordable solution than other strategies like supplementation or fortification. Once bio fortified varieties are created, they may be propagated and cultivated using current agricultural infrastructure without incurring a considerable additional expense.

Sustainability and Resilience: The nutritional value of staple crops is improved via biofortification, which also increases their resistance to environmental stresses and decreases their need on outside assistance. This can promote nutritional self-sufficiency while assisting communities in developing resilience against climate change and food poverty.

Biofortification : Concept and Methods

a. Explanation of Biofortification as a Strategy to Enhance Nutritional Value

In order to improve the nutritional value of food crops, biofortification is a technique used to increase the concentration of vital vitamins and minerals in their edible sections. The objective is to enhance the nutritional status of communities, particularly those suffering from hidden hunger or vitamin shortages. Biofortification incorporates nutritional improvement directly into the crops themselves, in contrast to standard fortification, which adds nutrients to processed meals. In order to create crop types with higher quantities of certain minerals, including iron, zinc, vitamin A, vitamin C, and folate, biofortification is used. Either traditional breeding practices or cutting-edge biotechnology approaches can accomplish this. Biofortification offers a sustainable and affordable way to treat nutritional shortages in communities that largely rely on these crops for their daily meals by focusing on commonly eaten staple crops, including rice, wheat, maize, and pulses.

b. Different Approaches to Biofortification, including Agronomic, Genetic, and Breeding Techniques

Agronomic Approaches: Agronomic biofortification aims to increase crop absorption while maximizing nutrient availability in the soil. To increase the nutritional content of crops, this strategy uses tactics including nutrient management, soil improvements, and fertilization methods. For instance, altering the pH of the soil or adding particular micronutrients might help crops better absorbs nutrients.

Genetic Approaches: Introducing genes that are in charge of nutrient absorption or bioavailability into crop types is known as genetic biofortification. Using genetic engineering methods, such as introducing genes from other species with high nutritional contents into the crop's genome, it is possible to accomplish this. In order to produce crops with higher nutritional value, genetic biofortification tries to increase the plant's capacity to absorb, transport, and accumulate certain nutrients.

Breeding Techniques: Crop types with naturally increased nutrient content or bioavailability are chosen and crossed in breeding for biofortification. Utilizing natural genetic variety within a crop species, this method seeks to find and grow plants with enhanced nutritional properties. Breeding programs involve methods like marker-assisted selection, in which superior lines are chosen based on the usage of certain genetic markers linked to high nutritional content.

c. Examples of Successful Biofortification Programs and their Outcomes

Vitamin A Biofortification : Golden rice is one of the best-known foods that has been bio fortified with vitamin A. It is a kind of rice that has undergone genetic modification to generate beta-carotene, which is a vitamin A precursor. This bio enriched rice may help with vitamin A insufficiency, especially in areas where rice consumption is common.

Iron and Zinc Biofortification: The Harvest Plus program, a global biofortification endeavour, has successfully created iron and zinc bio fortified varieties of crops such beans, maize, wheat, and pearl millet. These kinds have been introduced and widely used in a number of nations, improving iron and zinc consumption and lowering the frequency of nutritional shortages as a result.

Vitamin C Biofortification: In order to treat vitamin C insufficiency in areas with limited access to fresh fruits and vegetables, vitamin C biofortification of crops is being investigated. There is continuing research to increase the amount of vitamin C in crops like tomatoes and peppers using breeding and genetic techniques.

Biofortification of Pulses

a. Overview of the Biofortification Potential of Pulses

Because pulses are so widely consumed and have such high nutritional content, pulses offer a huge potential for biofortification. Already a great source of protein, dietary fiber, and other necessary elements, these crops are. Bio enriched pulses can dramatically address nutrient shortages and improve the nutritional status of people that largely rely on pulses as a dietary staple by further strengthening their nutrient content. Pulses may be bio fortified using a variety of ways, including agronomic practices, genetic engineering, and traditional breeding procedures, due to their genetic diversity. Biofortification of pulses can help fight nutrient shortages that are common in communities all over the world by focusing on specific nutrients of concern, such as iron, zinc, and folate.

b. Nutritional Targets for Biofortification in Pulses

The primary nutritional goals for biofortification in pulses are to raise the levels of important minerals including iron, zinc, and folate. These vitamins and minerals are essential for correcting widespread micronutrient deficits seen in many areas.

Iron: Iron deficiency is a major global public health issue. The goal of bio-fortified pulses is to raise the iron content of the plant's edible sections. Another important factor is iron bioavailability, which is the ease with which the body can absorb and use iron. Maximizing the nutritional impact on human health by biofortification can increase iron bioavailability.

Zinc: Many communities suffer from zinc deficiency, particularly in regions where cereal-based diets are the norm. Given that pulses are frequently eaten with staple cereals, biofortification of pulses with more zinc can help to satisfy dietary zinc needs. To maximize nutritional absorption, zinc bioavailability in bio fortified pulses must be improved.

Folate: Folate commonly referred to as vitamin B9, is crucial for healthy cell development and division, making it especially crucial during pregnancy. In order to counteract folate deficiency, which is linked to poor pregnancy outcomes and baby neural tube abnormalities, pulses can be bio fortified with more folate.

c. Biofortification Techniques Specific to Pulses

Seed Priming: Seed priming is a technique where seeds are soaked in a nutrient solution before planting to enhance their germination, early growth, and nutrient uptake. Priming pulses with specific micronutrients can improve their nutrient content and bioavailability. For example, iron and zinc priming solutions can be used to enrich pulse seeds with these nutrients.

Micronutrient Foliar Sprays: Foliar application of micronutrients involves spraying nutrient solutions directly onto the leaves of pulse plants. This technique allows for the direct uptake of essential nutrients, bypassing potential limitations in soil nutrient availability. Foliar sprays can be used to deliver specific micronutrients, such as iron and zinc, to enhance their content in pulses.

Breeding Methods: Conventional breeding techniques play a crucial role in bio fortifying pulses. Breeders select and cross varieties with naturally higher nutrient content or bioavailability, focusing on improving the nutritional traits of interest. Marker-assisted selection and other breeding approaches are employed to identify and develop bio fortified pulse varieties with enhanced iron, zinc, and folate content.

Breeding Methods in Biofortification of Pulses

Conventional breeding techniques: By enhancing their nutritious properties, conventional breeding methods help bio fortify pulses. In order to create bio fortified pulse varieties with increased iron, zinc, and folate content, breeders use a variety of tactics to choose and cross varieties with naturally greater nutrient content or bioavailability. Marker-assisted selection is one of the main techniques used in conventional breeding for biofortification.

Marker-assisted selection (MAS): A breeding strategy called marker-assisted selection (MAS) includes finding and using genetic markers linked to desirable qualities. Breeders look for genetic markers associated with high nutritional content or bioavailability in pulses when bio fortifying crops. Through the use of these markers as indicators, breeders may selectively produce plants that have the necessary nutritional characteristics. For instance, breeders may find genetic markers linked to high iron content or enhanced iron absorption in the production of pulses reinforced with iron. With the use of these markers, breeders may choose parent plants that already possess the desired qualities and cross them to produce offspring that are more likely to have increased iron content or absorption. The iron content of the resulting bio fortified pulse types can be gradually increased via several cycles of selection and breeding. Similarly, standard breeding techniques may be used to bio fortify pulses with zinc and folate. Breeders look for genetic markers linked to high levels of zinc or folate and utilize those markers as selection criteria for breeding new animals. Breeders can boost the probability of producing offspring with increased zinc or folate content by mating parent plants with appropriate marker profiles.

Phenotypic selection, which includes visually evaluating and choosing plants with desirable features, is another component of conventional breeding. Breeders can analyze the nutritional content or bioavailability of pulses in the context of biofortification by conducting laboratory investigations or evaluating features linked to nutrient uptake or usage. Furthermore, desirable features from wild or landrace varieties are introgressed into farmed pulse crops via breeding techniques including hybridization and recurrent selection. This increases the genetic variety and nutrient-improving potential of pulse types that have been bio-fortified.

Bioavailability and Health Benefits

a. Understanding the Bioavailability of Bio fortified Nutrients in Pulses

The term “bioavailability” describes how well the body can absorb and use the nutrients included in food. It is crucial to take into account the bioavailability of the added minerals, such as iron, zinc, and folate, in the context of bio fortified pulses to ensure their efficient usage. The type of nutrient, the presence of other components in the food matrix, and certain physiological circumstances are only a few of the variables that might affect how bio available nutrients are in pulses. For instance, the presence of phytates and other anti-nutritional elements that might limit iron absorption can decrease the bioavailability of iron in pulses. Nevertheless, biofortification initiatives seek to create pulse variations with more bio available forms of nutrients, taking into account the elements that might improve absorption and utilization. Pulses that have been bio fortified often have an increased nutritional content that is more readily available to the body, improving absorption. For instance, bio fortified pulses could include more non-heme iron, the type of iron that is mostly present in plant-based meals. For optimum absorption, non-heme iron needs co-factors such as vitamin C. Therefore, to increase the bioavailability of iron, bio enriched pulses may also contain increased quantities of vitamin C or other enhancers of iron absorption.

b. Exploring the Potential Health Benefits of Bio fortified Pulses

Consuming bio enriched pulses can improve overall nutritional status and treat vitamin deficiencies, which can lead to considerable health advantages. Consuming pulses that have been bio fortified may provide certain health advantages, such as:

Improved Micronutrient Status: Consuming pulses that have been bio fortified can help increase consumption and enhance status of micronutrients including folate, iron, and zinc. This can assist in preventing and treating micronutrient deficits linked to negative health effects.

Reduced Risk of Nutrient Deficiency-Related Disorders: Consuming pulses that have been bio-fortified can lower your chance of acquiring illnesses that are caused by nutritional deficiencies. Increased consumption of iron from bio-fortified pulses, for instance, can help treat iron deficiency anaemia, while increased folate content can help prevent neural tube abnormalities and other folate deficiency-related diseases.

Enhanced Cognitive Development: It’s essential for good cognitive development, especially in youngsters, to consume enough iron and zinc from bio fortified pulses. These nutrients are crucial for brain health and neurodevelopment, and pulses that have been bio fortified with them can enhance cognitive performance.

Increased Immunity: Immune system health can be affected by nutritional inadequacies, leaving people more vulnerable to infections and illnesses. Immune function may be improved by eating pulses that have been bio fortified, which also improves general health and disease resistance.

c. Case Studies and Scientific Evidence Supporting the Efficacy of Bio fortified Pulses

The effectiveness and impact of bio-fortified pulses in correcting nutritional shortages and enhancing health outcomes are demonstrated by a number of case studies and scientific investigations. Examples include

Iron Bio fortified Beans in Rwanda: A study conducted in Rwanda showed that consumption of iron bio fortified beans significantly improved iron status and reduced iron deficiency in women of reproductive age. This demonstrates the effectiveness of bio fortified pulses in combating iron deficiency.

Zinc Bio fortified Lentils in India: Research conducted in India demonstrated that consuming zinc bio fortified lentils improved zinc status and reduced the prevalence of zinc deficiency in children. The bio fortified lentils effectively increased dietary zinc intake and improved zinc absorption.

Folate Bio fortified Chickpeas in Australia: Studies conducted in Australia showed that consuming folate bio fortified chickpeas increased folate status and improved markers of folate metabolism in individuals at risk of folate deficiency. Bio fortified chickpeas contributed to increased dietary folate intake and improved folate bioavailability.

Implementation and Adoption of Bio fortified Pulses

a. Challenges and Considerations in Implementing Biofortification Programs for Pulses

Implementing biofortification programs for pulses can present a number of difficulties and calls for careful thought. Several significant issues and problems include:

Genetic Diversity: Pulses have a diverse genetic makeup, thus choosing the right cultivars and features to improve are necessary for bio fortifying them. It is essential to comprehend the genetics of pulse crops and how they interact with biofortification methods to guarantee successful deployment.

Agronomic Techniques: Adopting certain agronomic techniques to improve nutrient absorption and bioavailability may be required to implement biofortification initiatives. For farmers to improve crop management practices including seed priming, micronutrient foliar sprays, and sensible fertilization procedures, this necessitates knowledge dissemination and training.

Nutrient Stability: For the bio-fortified nutrients to maintain their enhanced nutritional content and be readily available for intake during processing, storage, and cooking, they must be stable. In order to prevent nutrient losses and preserve the advantages of biofortification, proper post-harvest handling and storage procedures must be put in place.

Consumer Acceptance: Promoting awareness of the advantages and safety of bio-fortified pulses among consumers is essential for their adoption. Consumer acceptability may be boosted by educating people about the nutritional benefits and clearing up any misconceptions or worries they may have regarding biofortification.

Policy Support: Support from policymakers is necessary for the execution of biofortification projects and their incorporation into agricultural and dietary guidelines. In order to guarantee the quality and effectiveness of bio fortified pulse crops, governments and politicians play a crucial role in encouraging biofortification, offering financial incentives, and setting laws and standards.

b. Strategies for Promoting Adoption of Bio fortified Pulses

A multifaceted strategy is needed to encourage farmers, consumers, and governments to use bio enriched pulses. Several methods to encourage adoption include:

Farmer Involvement: Including farmers in training programs, workshops, and demonstration plots will help them become more knowledgeable about biofortification methods and increase their capacity. Farmers may be encouraged to use bio fortified pulse crops by giving them access to better bio fortified seed types, technical assistance, and market connections.

Consumer Education and Awareness: Promoting pulses that have been bio-fortified to consumers through nutrition education campaigns and awareness initiatives can help increase demand for them. Consumer acceptability and demand may be raised by informing people about the nutritional advantages and possible health effects of consuming bio-fortified pulses through a variety of outlets, including the media, community outreach, and educational materials.

Public-Private Partnerships: Working with businesses in the private sector, such seed suppliers, food processors, and retailers, can make it easier to produce, sell, and distribute bio-fortified pulse crops. Public-private collaborations may take use of the advantages of both sectors to encourage the use of bio-fortified pulses and maintain a sustainable supply chain.

Policy Advocacy: Developing an enabling environment requires working with politicians to include biofortification in national agriculture and nutrition plans. Promoting beneficial regulations such as payments to farmers, requirements for product quality, and rules for purchasing might hasten the uptake and accessibility of bio-fortified pulse crops in the market.

c. Successful Examples of Bio fortified Pulse Initiatives and Their Impact on Communities

Numerous bio enriched pulse projects have had great success raising community nutrition and correcting micronutrient shortages. Examples that stand out include:

Iron Bio fortified Beans in Rwanda: Rwandan Agriculture Board and Harvest Plus launched a biofortification initiative that was specifically focused on iron-bio fortified beans. The initiative effectively expanded the availability and consumption of iron-rich beans via research, development, and promotion, which enhanced iron status and decreased iron insufficiency among vulnerable people.

Zinc Bio fortified Lentils in India: Lentil cultivars with zinc biofortification were created and promoted in India by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). These kinds, together with specific nutrition education initiatives, have helped raise dietary zinc consumption and enhance community zinc status, especially among women and children.

Vitamin A Bio fortified Cowpeas in Nigeria: Nigerian cowpea cultivars with vitamin A bio fortification were developed by the International Institute of Tropical Agriculture (IITA). This program sought to alleviate vitamin A deficiency in at-risk groups. Consumers now eat more vitamin A and have better vitamin A status thanks to the introduction of these bio-fortified cowpeas.

Future Perspectives and Conclusion

a. Emerging Trends and Technologies in Biofortification of Pulses

As new trends and technology emerge, the subject of biofortification continues to develop, opening up new opportunities for improving the nutritional content of pulses. Key technologies and trends include:

Genomic Selection: Genomic selection, a method for predicting breeding line performance using genetic markers and genomic data, has enormous promise for speeding the creation of bio-fortified pulse varieties. This strategy may make it easier for breeders to choose plants with the needed nutritional characteristics, speeding up the process of biofortification.

Gene Editing: By precisely altering certain genes important for nutritional content or bioavailability, gene editing technologies like CRISPR-Cas9 have the potential to revolutionize biofortification. With the use of these technologies, it may be possible to make precise, targeted changes to the pulse genome that will improve the nutritional profiles.

Nutrigenomics: By examining the interactions between genes and nutrients, nutrigenomics can shed light on how nutrients in pulses are absorbed and used. Nutrigenomics, the study of genetic influences on food metabolism in humans, can help in the development of bio-fortified pulse types that are suited to different dietary requirements.

Biofortification Combinations: Combinations of bio fortified elements in pulses can have a synergistic effect that can improve the nutritional value of the food. For instance, increasing the iron and vitamin C content of pulse types can help people absorb iron more effectively because vitamin C increases the absorption of non-heme iron.

b. Potential for Scaling Up Biofortification Efforts and Reaching Wider Populations

To optimize the positive effects of bio fortified pulses on public health, initiatives must be scaled up and extended to larger populations. There are several methods that can help biofortification initiatives grow:

Strengthening Research and Development: Continued investment in research and development is essential to develop new bio fortified pulse varieties, optimize biofortification techniques, and address specific nutrient deficiencies prevalent in different regions.

Collaboration and Partnerships: Collaboration among researchers, farmers, governments, and international organizations is key to scaling up biofortification efforts. Partnerships can help mobilize resources, share knowledge and expertise, and facilitate the adoption and dissemination of bio fortified pulse crops.

Farmer Empowerment and Market Access: Empowering farmers through training, capacity building, and providing access to quality seeds and technical support can promote the adoption and production of bio fortified pulses. Additionally, establishing market linkages and ensuring fair prices for bio fortified pulse crops can incentivize farmers to engage in their production.

Policy Integration: Integrating biofortification into agricultural and nutrition policies is crucial for its mainstreaming and sustainability. Governments can provide policy support, including financial incentives, quality standards, and procurement guidelines, to promote the adoption and availability of bio fortified pulse crops in local markets.

c. Conclusion Summarizing the Importance and Potential of Biofortification of Pulses

The biofortification of pulses has enormous potential and significance for treating nutrient shortages and enhancing the nutritional status of communities across the world. Increasing the nutritious content of pulses, a frequently eaten staple food, can have a major influence on public health. Pulses that have been bio fortified provide a practical and affordable way to address nutritional deficiencies, especially in areas with limited resources. Bio-enriched pulses can contribute to better micronutrient consumption, avoid deficiency-related diseases, and advance general health and wellbeing by raising the content and bioavailability of vital elements including iron, zinc, and folate. The future of pulse biofortification is bright thanks to new trends and technologies, including genomic selection, gene editing, and nutrigenomics. These developments present chances to improve pulses' nutritional value even more and modify them to satisfy certain dietary requirements. In order to fully use biofortification, it is crucial to advance research and development, foster partnerships and collaboration, give farmers more authority, and include biofortification into programs and policies. We can make considerable progress in eliminating nutrient shortages and enhancing the nutritional quality of communities all over the world by stepping up biofortification activities and reaching larger populations. Therefore, the biofortification of pulses is an essential technique for alleviating nutritional shortages and enhancing public health, and the agriculture and nutrition sectors should prioritize its application and extension.

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Chapter 2

Nutritional Security through Vegetables

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The nutrient deficiency can be cost effectively rectified by certain effective Govt. policy, supplementary nutritional programmes to the children and the expectant and lactating mothers and other poverty alleviation programmes. In India, nearly half of the rural children are suffering from malnutrition. On one side there is non-availability of food and on other side there is change in consumption pattern of affordable people.

To eliminate malnutrition, diversified food including of minor millets, pulses, fruits and vegetables should be included in the diet. Healthy diet in terms of quality (e.g., intake of animal protein, vitamins, minerals and so on) to be ensured.

Importance in different sectors

First of all, nutrition should be an important component of professional and school education. People particularly vulnerable sections i.e. pregnant and lactating women should be made aware of nutritional value of essential food items which are of must needed for a healthy diet. Illiterate people can be educated through their school going children and grandchildren. And then, it should be made available to all particularly to women and children. Education, particularly of women is important for optimum utilization of the available services and creating demand. School children, youth and pregnant women who are the future of India should be sensitized more about nutritive value of food and its importance and the effect of its deprivation on body and its development. Here comes the role of extension agents who are the change agents in a social system, shall be exploited in this direction too.

The second green revolution must be nutrition oriented, which was neglected in production oriented Green Revolution, to have inclusive and equitable growth and development of our country. The platforms of various schemes like National Horticulture Mission, National Food Security Mission, Rashtriya Krishi Vikas Yojana, National Rural Health Mission, Mahatma Gandhi National Rural Employment Guarantee Scheme, Strengthened Integrated Child Development Services (ICDS), Enlarged Mid-Day Meal Programme in schools etc., which directly or indirectly oriented towards nutrition to get the maximum mileage out of the current efforts. And the various schemes of different ministries which directly or indirectly influence nutritional security shall be integrated together with other development schemes as nutrition affects overall development of the country.

According to latest report of Ministry of Statistics and Programme implementation (2012), 48 % of the country's children under the age of five years are stunted, which indicates that half of the India's children are chronically malnourished. The worst performing states with underweight children under five years of age are M.P., Jharkhand and Bihar. Therefore, the food security and nutritional security are the important issues in national development programmes.

The diversified and highly nutritive vegetables are of great importance in alleviating malnutrition. The dieticians advocate intake of 125g leafy vegetables, 75g other vegetables and 100g root and tuber vegetables every day to make our diet balanced. Vegetable are rich source of carbohydrates, proteins,

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vitamins, and minerals, hence called as protective foods.

1. Increasing the availability of a diverse range of safe vegetables

To meet the growing market demand for vegetables at a?ordable prices, production must increase. This can be achieved through di- versi?cation of staple crop systems to include vegetables as well as intensi?cation of existing specialized vegetable systems, particularly in peri urban areas (e.g., Beed et al., 2015).

2. Ensuring that vegetables are safe to eat

Most vegetables are highly susceptible to damage from insect pests and plant diseases in the production phase. Certain pests and diseases can cause blemishes or odd shapes as well as reduce yields. Since consumers place a high value on the appearance of fresh produce offered in markets, farm managers often turn to excessive use of pesticides to reduce these economic risks. The use of pesticides is much more intense on high value crops than on low-value crops and farmers tend to spray preventively to protect their investment.

Food safety goals require policymakers to de?ne suitable standards for vegetable production and handling and to put in place systems for monitoring compliance, including regular testing for pesticide residues and pathogens at major markets and public dissemination of the test results.

1.1. Improving on-farm productivity

On-farm productivity of vegetables varies widely. This variability indicates the potential to improve on-farm productivity through innovation. We focus here on three key areas of innovation: varietal improvement, pest and disease management, and protected cultivation.

1.1.1. Improved vegetable varieties

The availability of quality vegetable seeds is fundamental to increasing on-farm productivity. The rising supply of global vegetables has been linked to investments in research and development of hybrid varieties, and the marketing of seeds appropriately matched to speci?c production constraints. Policies that have supported private investments in quality vegetable seed development and production have paid o? in terms of vegetable supply volumes.

1.1.2. Safe and sustainable pest management

Farmers often identify crop pests and diseases as their main sources of risk because they reduce yield and negatively a?ect the marketability of the produce. Indications are that the intensity of pest and disease pressures may increase due to climate change (Bebberetal., 2013) so methods of mitigation will assume even greater importance going forward. World Vegetable Center experience indicates three key sets of interventions could help: use of biocontrol methods, grafting high-yielding seedling son to resistant root stocks, and investing in protected cultivation systems.

Bio-control methods (i.e. the use of living organisms such as predator insects or parasites to control pests) have much potential to replace chemical pesticides, thereby improving food safety and lowering production risks. However, the di?usion of such methods is hampered in many countries by the rapid expansion of global trade in chemical pesticides and the high satisfaction of farmers with the e?ectiveness of chemical pesticides combined with limited risk awareness and knowledge of biocontrol methods (Schreinemachers et al., 2015). Regulatory frame-works often treat biopesticides (i.e., pesticides derived from natural materials such as of the neem plant) the same as chemical pesticides, which hampers the commercialization of safer methods (Srinivasan, 2012).

1.1.3. Protected cultivation

The incidence of pests and diseases can also be lowered using protected cultivation systems. Such systems enable producers to gain more control over their production environment. They can also allow farmers to produce vegetables outside the “regular” season (often de?ned by rainfall and temperature). Production brought to market outside of this season can realize signi?cantly higher prices. Technologies range from simple rain shelters made of bamboo and plastic sheets to fully equipped greenhouses allowing for year-round cultivation. The use of protected cultivation methods is spreading rapidly across Asia (Kang et al., 2013; Nair and Barche., 2014). *Reducing postharvest losses*

1.2. Improving market access

Increased access to domestic, regional and international markets for vegetables can provide important income incentives for farmers to enter vegetable production. In Ghana, producers have successfully broken into the vegetable export business by producing non-traditional vegetables such as fresh French beans and Asian vegetables to exacting market speci?cations, packaged to retain freshness, and shipped by air or sea directly to supermarkets in Europe.

Home gardens and rural vegetable consumption

Name	Main occurrence	Effectiveness	Deficiency
Vitamin A (Retinol)	Pro-vitamin A in carrots, muskmelon, tomato and leafy vegetables.	Normal growth, function and protection of skin, eyes and mucous membrane.	Growth stop, night blindness and xerophthalmia in infants.
Vitamin B1 (Thiamine)	Palak, Pea is good source.	Important for the nerve system, liver damage, inefficiency, pregnancy, mosquito protection (high-dosed), production of energy,	Heavy muscle- and nerve disturbances, tiredness, cardiac insufficiency, beriberi
Vitamin B2 (Riboflavin)	Green leafy vegetables like palak, curry leaves, radish leaves, chilli, spinach etc.	Important for body growth, well for skin, eyes and nails, important energy bringer, oxygen transport.	Skin inflammation, brittle nails, anaemia, callus attrition.
Vitamin B3 (**Niacin**, Nicotine acid)	peas, palak, amaranth and gourds.	Building and degradation of fat, protein and carbohydrates, good sleep.	Skin and mucosa inflammation, headache, trembling, sleep disturbance, depressions, pellagra.
Vitamin B5 (Pantothen acid)	asparagus, leafy vegetables	Against turning grey, hair loss, hair and mucous membrane illnesses, necessarily for the dismantling of fat, proteins and carbohydrates	Nerve malfunctions, bad healing of wounds, weakened immune system
Vitamin B6 (Pyridoxin)	potatoes, green beans, cauliflower, carrots	Travel sickness, neuralgia, liver damage, premenstrual syndrome, digestion of protein, most important hormone in pregnancy together with folic acid,	Intestine problems, bad skin, tiredness, rough corners of the mouth.
Vitamin B7 (**Biotin**, Vitamin H)	cauliflower	loss in growth of hairs, liver damage, assists metabolism,	States of exhausting, skin inflammations, muscular pains, hair loss,
Vitamin C (ascorbic acid)	potatoes, paprika, tomatoes, collard, spinach, vegetables, radish	Inflammation and bleeding-restraining, assists the body's defences, protects cells against chemical destruction, activates enzymes, structure of connective tissue, bones and dental enamel, faster healing of wounds, stabilisation of psyche	Gum-bleed, tiredness, joint pain and headache, bad healing of wounds, lack of appetite, scurvy, inefficiency
Vitamin E (Tocopherole)	Sunflowers salsify, peperoni, collard,	Stabilization of the immune system, anti-inflammatory, cell replacement, protection from radicals, modulates cholesterol level and hormone household,	(rarely) amblyopia, tiredness, amyotrohia, dislike, reproduction problems
Vitamin K (Phyllochinone)	green collard, green vegetable, bulbs, tomatoes, cress	Necessary for formation of the blood clotting factors	High doses of vitamin A and E work against vitamin K.

Home garden interventions designed with nutritional quality in mind pair hands-on training in vegetable production with nutrition and health behavioral change communication (e.g., World Vegetable Center, 2016). Such interventions simultaneously address vegetable avail-ability, access, demand, and utilization. This multipronged approach is especially e?ective at increasing vegetable consumption among poor rural households vulnerable to micronutrient de?ciencies (DFID, 2014; Galhenaetal., 2013; Olneyetal., 2009; Schreinemachersetal., 2016a).

School meals

School meals provide a good entry point for in?uencing children's diets; recent studies provide sound evidence for their nutritional impact (Global Panel, 2015; Kristjansson et al., 2006). Nutritional bene?ts can be increased when school meal programs include fresh fruit and vegetables along side food staples, pulses, vegetable oil, dairy and meat.

School garden programs involving a combination of nutrition and health education with hands on experience in gardening is one such integrated approach to in?uencing children's food behavior toward healthier food choices, including fruit and vegetables. School garden interventions aim to expose children at a young age to fruit and vegetables and to

Nutritive value of vegetables

Vegetable	Moisture (g)	Protein (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)
Ash gourd	96	0	30	20	1
Bitter gourd	92	2	20	70	1
Bottle gourd	96	0	20	10	0.7
Potato	74	1.6	10	35	0.7
Tomato	94	1.2	48	26	0.4
Chilli	85	2.9	30	80	1.2
Sweet pepper	92	1.3	10	0	1.2
Cabbage	92	1.4	46	38	0.8
Cauliflower	91.7	2.4	30	76	17
Muskmelon	95.2	0.3	32	14	1.4
Watermelon	95.8	0.2	11	12	7.9
Carrot	82.2	0.9	48	30	0.6
Onion	86.8	1.2	180	50	0.7
Garlic	62.8	6.3	30	310	1.3
Pea	72	7.2	20	139	1.5
French bean	91	1.7	50	28	1.7

(Krishisewa.com)

develop eating habits and food attitudes during childhood that may persist through to adulthood.

Nutritional components in Vegetables

1. Carbohydrates

Carbohydrates are chief source of energy in the food. It is also called as protein sparing food. Daily requirement of CHO is 400-500 g. Vegetables like potato, sweet potato, cassava, elephant foot yam, taro, garlic, pea and onion are good source of carbohydrates. In fact, sweet potato is cheapest source of calorie.

2. Proteins

Proteins are complex nitrogen containing organic compounds. They constitute a major part of protoplasm. Daily requirement of proteins is 60-70 g. Vegetables contain less protein compared to the product of animal origin. Although sulfoamino acids (methionine and cystine) are most of the time limited in vegetable proteins. Peas, beans, and leafy vegetables are good source of proteins.

3. Flavonoids

Like quercetin, kaempferol other flavonoids are present in vegetables. Quercetin is present in onion. The flavonoids containing vegetables help to prevent high blood pressure.

4. Folates

Folates reduce the risk of heart disease, strokes and colon cancer. Their deficiency causes anaemia in infants and pregnant women. Leafy vegetables are rich source of folic acids.

5. Vitamins

Vitamins are biologically active compounds and are essential for normal physiological process. Specific vitamin deficiency produces characteristics symptoms.

6. Minerals

Minerals play major role in functioning of physiological activities. They are components of various vital body constituents. As for example:

Calcium is essential component of bones and teeth. Iron is important component of haemoglobin. Phosphorus along with C, H, O and N are the components of DNA. Iodine is vital constituents of thyroid hormones, thyroxin and triiodothyronine.

Mg is required for cellular metabolism. Zinc is cofactor of many enzymes and performs a range of functions in body.

7. Dietary Fibre

Plant cell walls comprising of cellulose, pectin, xylanase main source of dietary fibre. Dietary fibre provides protection against some cancer, lower blood cholesterol etc. Gums and pectin reduce the post prandial level of glucose in blood.

Conclusions

Finally, vegetables are a vital source of nutraceuticals that promote health by playing a protective role in the body. Vitamin C, previously discussed, is part of the family of terpene compounds that protect cells from free radicals and ionizing radiation. Some terpenes are very protective of vaginal, uterine, and cervical tissues. Glucosinolates found in cruciferous vegetables and allyl sulfides from onions and garlic have important functions in building and regulating the immune system. These compounds, along with isoflavones, flavonoids, indoles, and other nutraceuticals improve and protect the circulatory system, enhance detoxification activity in the liver, and prevent or suppress various kinds of cancer. While much remains to be discovered about many of these compounds and their function in preventing disease, their value as a component of a healthy diet is clear. Vegetables are a valuable component of any diet, contributing minerals, vitamins, and other nutrients which may otherwise be lacking. These compounds can enhance human growth and development, improve general health, and strengthen immune responses to combat disease. In situations where dietary choices are limited, or when immune systems are compromised, vegetable consumption may make the difference between normal health and life-threatening disease.

Vegetables are nutritional powerhouses, key sources of micro-nutrients needed for good health. Vegetables add diversity, ?avor, and nutritional quality to diets. A strengthened focus on vegetables may be the most direct and most a?ordable way to deliver better nutrition for all. Vegetables are also economic engines for productive, pro?table agricultural economies. Intensi?ed vegetable production has the potential to generate more income and employment than other segments of the agricultural economy, making vegetables an important element of any agricultural growth strategy.

Today, however, neither the economic nor the nutritional power of vegetables is su?ciently realized. The longstanding focus on staple food crops must be adjusted to take in a broader view. Governments and donors need to raise the priority given to increasing the productivity of vegetable production systems, reducing postharvest losses, and increasing a?ordability and market access. Measures to ensure that vegetables are safe are fundamental. With a growing understanding of the linkages between dietary quality and health, policymakers must also be prepared to support additional interventions to promote vegetable consumption. Elimination of the persistent gap between recommended and actual intakes of vegetables would go a long way to achieving the Sustainable Development Goals related to improving food and nutrition security and good health. Now is the time to direct increased attention to the vegetable sector, providing increased opportunities for generating employment and in- come, especially for new entry and smallholder farmers, as well as promoting more diverse, healthy, high-quality diets for all.

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Chapter 3

Promoting Self-Care in Marginalized Communities : Understanding the Effectiveness of Interventions among Rural and Tribal Women

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Abstract

Self-care is the ability to take care of one's own physical, psychological, emotional and social wellness and wellbeing. Self-care allows individuals to have a healthier, happier and more fulfilled life by assisting in reducing anxiety, depression and burnt-out, in improving coping abilities, inner satisfaction, strong interpersonal relationships and in finding a sense of purpose in life. The present study aimed to enhance self-care levels among women in Adilabad and Komarambheem Asifabad districts of Telangana State. Quasi experimental research design was used and a sample 0f 120 women including 60 rural and 60 tribal participants aged between 25-50 years were drawn by using purposive random sampling method. The findings of the study revealed that the women with low self-care were upgraded to high followed by moderate levels of self-care after exposed to intervention. The women's capacity to practice physical, psychological, emotional and social care had been improved by the self-care intervention. The findings of this study can serve as a foundation for future research in the field of self-care interventions.

Key words : *Self-care, tribal, rural, women and intervention.*

Introduction

Self-care is a skill that allows an individual to have a healthier, happier and more fulfilled life as it assists in promoting overall physical, mental, emotional and social well-being by reducing anxiety, depression and burnt-out feelings which are associated with increased self-esteem, happiness and finding a sense of purpose in life (Hemmatimaslak and Hashemloo, 2012) as well as life satisfaction and hope (Erci *et al*. 2017). Thus self-care is not only important to promote health but also helps in finding a sense of purpose in life which leads to self-fulfilment. But studies stated that women had relatively lower levels of physical, psychological/ emotional, spiritual, intellectual, social and recreational self-care (Shiri-Mohammadabad and Afshani, 2021). Women particularly those living in rural and tribal areas had low levels of self-care activities and higher degree of ignorance when compared to urban women (Hakimi *et al.* 2018 and Auttama *et al*. 2021). A significant positive association between focused self-care and subjective well-being was found and demonstrated a growing need for greater frequency of self-care practices and interventions in order to improve status of well-being (Chatterjee and Jethwani, 2020). Thus, Education on health promoting models is essential to enhance self-fulfillment levels (Behnam-Moradi *et al*. 2019). Soderhamn *et al* (2001) also stated that increased self-care ability in adults leads to self-fulfilment. Maslow's theory states that unmet deficiency needs result in lower levels of self-actualization and fulfilment.

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Review of Literature

Auttama *et al*. (2021) had taken up a study to identify factors associated with self- esteem, resilience, mental health and psychological self-care among university students from four majoring in Public Health at University of Phayao in Northern Thailand. The results of study found that more than half of the individuals were having low levels of psychological self-care.

Sandhya and Sreedevi (2021) conducted a study on effect of intervention on self- care levels of 60 farm women. The interventional activities on maintaining healthy diet patterns, sleep patterns, personal grooming, hygiene practices, paying attention to physical and mental health symptoms helped in bringing desirable changes in the attitude of farm women towards self-care. Further the study also found that there was a significant mean difference in self-care levels of farm women during pandemic before and after the intervention at 0.01 level of significance and helped in bringing positive attitudes towards self-care among farm women.

Shiri-Mohammadabad and Afshani (2021The findings revealed that women from marginal communities had relatively lower levels of physical, psychological/ emotional, spiritual, intellectual, social and recreational self-care.

Yoshimura *et al.* (2021) assessed self-care among 175 older adults aged 65 years or older living in a rural area and found that self-care scores on one's attention on self- care, acquisition and maintenance of health management methods, adjustment of physical condition and ability to receive valid support scores were significantly higher for participants aged = 75 years compared to those aged < 75 years.

Andrew (2020) examined the effect of a self-care educational intervention on nursing student resilience. The educational intervention had a strong positive effect on resilience scores (effect size of r=72%, $p<0.05$). It was also found that Eighty-six percent of the participants believed that the intervention increased their capabilities for self-care, especially in sleep, spending time outside, hydration, nutrition and physical stretching exercises but not in journaling. Eighty-one percent stated that they would be likely to seek professional help if needed.

Miller *et al.* (2019) conducted an exploratory study to examine the self-care practices of self-identified women social workers (N=2,934) throughout the United States. The results indicated that social workers in the sample engage in moderate self-care practices. Overall, the findings of this study indicated a need to improve self-care practices among women.

White *et al.* (2019) evaluated the effectiveness of an online self-care intervention for 187 graduate-level students to prevent worsening mental health. The intervention consisted of behaviour change assignments designed to increase health-promoting behaviours within four domains (nutrition, physical activity, mental health, social support). Students received bonus points for maintaining health behaviours for the duration of the 12-week semester. It was found that intervention had improved the health promotion behaviours over the course of the semester ($p<.001$), with the largest effect sizes for increases in fruit and vegetable intake and physical activity.

Hakimi *et al.* (2018) conducted a cross-sectional study on middle-aged women living in rural and urban areas of East Azerbaijan to compare self-care activities, barriers and information sources. The results of this study showed that women, particularly those living in rural areas had low levels of self-care activities like exercising regularly, eating enough fruits and vegetables and drinking enough fluids etc and also facing barriers such as a lack of resources (money, time, interest), a lower level of education and ignorance at higher degree when compared to urban women.

Leao *et al.* (2017) assessed the self-care levels of female health professionals and on impact of self-care intervention stress management, self-esteem and subjective well- being among female health professionals aged between 18 to 60 years old. The results revealed that self-care was being neglected and reported with inadequate hours of sleep, irregular hours of sleep, irregular physical activity, inadequate nutrition among most of the participants. But after exposed to self care intervention, self-esteem, lower stress levels and higher life satisfaction levels among women were enhanced when compared with control groups at 0.01 level of significance.

Research Methodology

A quasi-Experimental research design was adopted to study the effect of intervention program on self-care levels of rural and tribal women before and after the intervention. Adilabad and Komarambheem Asifabad districts of Telangana state were purposively selected for conducting the study. Telangana is the only south Indian state with tribal population of 9.34 percent out of its total population with most backward (Tribal welfare Department Telangana state, 2011 census). Purposive random sampling technique was used to select the sample. The sample consisted of 60 rural and 60 tribal women from selected mandals of Adilabad and Kumarambheem Asifabad districts. Thus, a total sample of 120 women was taken for the investigation. A self-developed scale was used to assess the self-care levels among women.

Criteria for sample selection

Women who are in the age group of 25-50 years.

Women who had been married for a minimum of one year.

Women who belonged to Rural and Tribal areas.

Women who were willing to attend "Self-care empowerment" intervention program.

Results and Discussion

The table-1 deals with the self-care levels of respondents prior to intervention. The self-care was studied in terms of taking adequate care of physical, psychological, emotional and social needs in their daily life. The data obtained on existing levels of self-care among rural and tribal women is discussed below :

Table-1 : Distribution of women based on levels of self-care before intervention (n1=60, n2=60, n=120)

S.No.	Self-Care	Rural (n_1)		Tribal (n_2)		Total (n)	
		F	%	F	%	F	%
1.	Low	30	50	39	65	69	58
2.	Moderate	21	35	14	23	35	29
3.	High	9	15	7	12	16	13
	Total	60	100	60	100	120	100

According to table-1, it was found that more than half of the of respondents (58%) had low level of self-care followed by moderate self-care (29%). Only few (13%) of the respondents had a high level of self-care. It clearly depicts that the majority of the rural and tribal women were not taking adequate care of their physical, psychological, emotional and social needs in their day to day lives. Psychological and emotional care was very poor among rural and tribal women when compared to physical and social care. It was also observed that tribal women were poor in overall self-care practices when compared to rural women.

With regard to physical and social self-care, it was noticed that both rural and tribal women were taking care of some physical and social needs such as maintaining enough sleep pattern, relationships with friends and family, etc but they were not taking adequate care for maintaining balanced diet, personal health and hygiene and doing physical exercises etc.

In relation to psychological and emotional care, it was found that majority of rural and tribal women were not taking adequate care of themselves which are essential for safeguarding emotional and mental health. They often become anxious, distress even for little disturbances, involve more in disruptive and unpleasant emotional reactions, not able to balance and cope with their emotions by keeping calm and comfortable during psychological upsets. They were often stressing themselves and experiencing anxiety and irritability even for the minor difficulties and little stressful conditions. Due to all these, they felt low about themselves, unable to pay attention to their self needs and loose interest to do things in their day-to day life. This might be due to most of the women being less educated, having poor attitudes towards self-care and least priority to self-needs and also less trained in practicing different aspects of self-care.

On par with the present findings, Shiri-Mohammadabad and Afshani (2021) reported that general self-care behaviours among women from low SES and marginal communities were found to be low when compared with the high SES group. Similarly, Hakimi *et al.* (2018) discovered that women from rural areas had low levels of self-care practices and experience more barriers than urban women. Likewise, Leao *et al.* (2017) also stated that self-care among female healthcare professionals was being neglected and reported inadequate and irregular hours of sleep, physical activity and insufficient nutrition. Apart from these Miller *et al*. (2019) found that the self-care practices among female social workers were at a moderate level and there is a need to improve self-care practices.

From the above results it can be concluded that the majority of rural and tribal women had inadequate self-care and there was a need for an intervention program to enhance their knowledge and skills related to various aspects of self-care to promote their sense of self- fulfilment.

Effect of intervention on self-care levels of women : The details of the effect of the intervention on levels of self-care are discussed below :

The above table-2 denotes the levels of self-care among women before and after receiving the intervention program. It can be inferred from the table that, most of the women enhanced their self-care practices after attending to intervention. It was observed that the percentage of women in low-level self-care category drastically reduced from 58% to 8%. Simultaneously women in the moderate self-care category enhanced from 29 % to 38% and high category from 13 % to 54%. This clearly indicates that both rural and tribal women with low self-care were upgraded to high followed by moderate levels of self-care. It denotes that the women's capacity to practice physical, psychological, emotional and social care had been improved by the self-care intervention. In addition, it was also noticed that self care levels

Table-2 : Distribution of women based on levels of self-care before and after intervention. (n1=60, n2=60n=120)

S. No.	Self-Care	Rural (n1)		Tribal (n2)		Total (n)	
		Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
1.	Low	30 (50%)	4 (7%)	39 (65%)	6 (10%)	69 (58%)	10 (8%)
2.	Moderate	21 (35%)	20 (33%)	14 (23%)	25 (42%)	35 (29%)	45 (38%)
3.	High	9 (15%)	36 (60%)	7 (12%)	29 (48%)	16 (13%)	65 (54%)
	Total	60 (100%)	60 (100%)	60 (100%)	60 (100%)	120 (100%)	120 (100%)

Figures in the parenthesis indicate percentages)

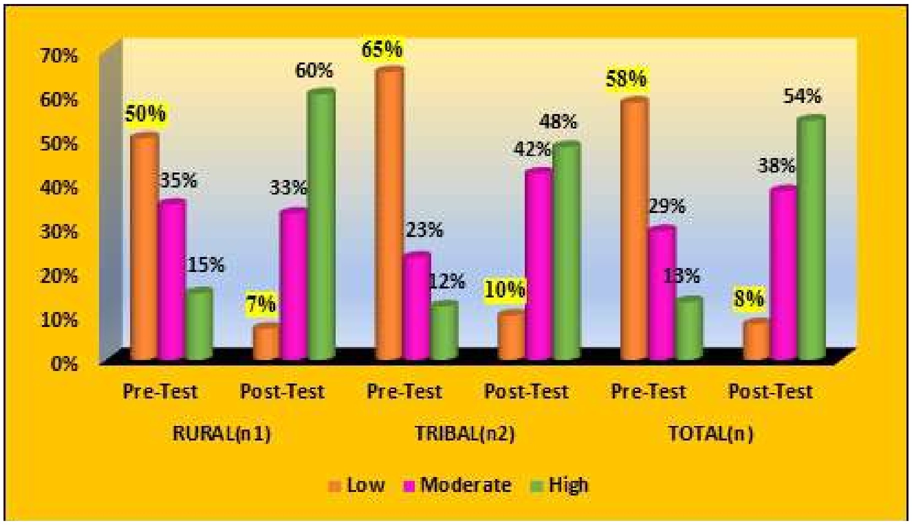

Figure-1 : Self-care levels of rural and tribal women before and after intervention.

improved slightly more among rural women when compared to tribal women after being exposed to the intervention (Figure-1).

It can be inferred that women who were very poor in maintaining an adequate balanced diet, personal health and hygiene and poorly motivated to practice exercises and yoga before intervention were able to maintain a healthy diet like consumption of more protein, vegetables, fruits and also started doing physical activities like yoga and meditation and practicing personal hygiene on regular basis after receiving the intervention.

The women who were not able to recognize and deal with their stress levels and uncomfortable emotions such as anxiety, anger and frustrations before intervention were able to identify and cope to some extent after being exposed to the intervention. They began to pay much attention and focus on their psychological and emotional health care aspects which were very poor and mostly neglected before the intervention. They became more conscious of their emotional state and careful about sources that trigger their emotions. They were able to keep themselves in comfortable and peaceful condition by staying calm and not reacting vigorously to situations. They were no longer staying with hard feelings even during disturbances and were able to reconcile back to their normal state and take part in their day-to-day activities with joy and interest which of these were lacking prior to the intervention.

It is also important to know that, women who were not able to practice enough sleep hours and maintaining social relationships with friends and family to some extent prior to the intervention were well motivated to practice enough sleep hours and spending good quality and quantity time with friends and family. They began to spend more time in social gatherings and activities. On the whole, it can be observed that the majority of the women are motivated to improve their self-care by paying enough attention to their physical, psychological, emotional and social care aspects after being exposed to the intervention. It was also noticed that physical and social self-care practices were adopted and practiced more by rural and tribal women than psychological and emotional care practices.

The above results are in line with Andrew (2020) who found that the self-care intervention on the importance of journaling, deep breathing, progressive muscle relaxation, stretching, yoga, grounding, maintaining good nutrition, hydration, sleep, spending time outside on regular basis increased self-care capabilities of nursing students. Correspondingly, White *et al.* (2019) also found that self-care intervention on nutrition, physical activity, mental health and social support had increased health-promoting behaviours among graduate students.

Thus, it can be concluded that intervention had enabled the women to take care of their physical, emotional, psychological and social self-care skills, as they realized the significance of self-care in different domains. Thus, the intervention planned for the present study helped the respondents to focus and prioritize their self-needs in order to be physically and mentally fit to meet the purpose of their lives.

Table-3 : Mean differences in self-care levels of women before and after intervention (n=120).

S. No.	Com-ponent	PRE-TEST		POST-TEST		t-value
1.	Self-care	Mean	SD	Mean	SD	8.46**
		30.35	7.59	36.70	6.10	

**p = 0.01 level of significance

Table-3 explains the mean score differences in women's self-care levels before and after the intervention. It is evident from the table that the mean scores of self-care levels were enhanced from 30.35 with SD 7.59 to 36.70 with SD 6.10 after exposure to the intervention. The calculated paired 't' value 8.46 was found to be statistically significant at 0.01 level. Hence, it can be inferred that the strategies used for self-care intervention such as the importance of self-care in different domains, consequences of poor self-care, exploring ways to improve self-care practices, monitoring and reviewing practices on daily basis helped in bringing desired changes in the attitudes and skills of rural and tribal women towards self-care and also to adopt healthy self-care behaviours.

In line with the present findings, White *et al.* (2019) explained that there is a substantial mean difference in health-promoting behaviours (nutrition, physical activity, mental health and social support) among experimental group compared with control group at 0.01 level of significance. Whereas Leao *et al*. (2017) revealed that self-care intervention had improved self-esteem and life satisfaction, reduced stress levels at 0.01 level of significance. Similarly, Sandhya and Sreedevi (2021) also found that self-care intervention helped rural farm women in adopting good self-care practices at a 0.01 level of significance.

Conclusions

The present study focused on promoting self-care practices among women had brought a significant positive effect in bringing desirable changes in knowledge, skills towards self-care. Which can lead to improved physical, psychological, emotional, and social well-being. By incorporating self-care into their daily lives, women can experience reduced anxiety, depression, and burnout, and enhance their overall quality of life. The findings of this study can serve as a foundation for future research in the field of self-care interventions. The results and conclusions drawn from this study may not be generalizable to other populations or regions without further research. Self-care interventions can empower women to take responsibility for their own health and well-being. By increasing self-care levels, women gain a sense of empowerment and autonomy over their own lives. They become more capable of managing their physical and emotional needs, making informed decisions, and prioritizing their well-being. This can have positive ripple effects on their personal and professional lives. Therefore, future studies should consider expanding the scope to include diverse populations, geographical locations, and age groups to establish broader applicability and generalizability of the findings. It can inspire further studies to explore different populations, interventions, and settings, leading to the development of more effective self-care programs and strategies.

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Chapter 4

The Desert Locust : A Threat to Livelihoods and Food Security

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Abstract

The Desert Locust (*Schistocerca gregaria*) is a formidable agricultural pest that poses a significant threat to livelihoods and food security in more than 60 countries worldwide. Renowned for its ability to migrate over vast distances and rapidly increase its population, the Desert Locust is considered the most important species of locust. This chapter explores the unique challenges presented by locust invasions, particularly during the swarming phase, when their behavior becomes highly destructive. Traditional practices, such as trap cropping, have long been employed to manipulate pest behavior, but modern approaches based on Integrated Pest Management (IPM) techniques are proving effective in locust control. These techniques include the use of neem-based insecticides mixed with spreading agents and aerial spraying of ULV insecticides. Additionally, raising farmer awareness and sensitizing local ecology groups are crucial for the successful management of the Desert Locust. The socioeconomic implications of locust invasions, including acute food insecurity in arid and semi-arid regions of Africa, the Middle East, and Southwest Asia, further underscore the urgency of finding sustainable solutions. By understanding the life cycle and swarm behavior of the Desert Locust and implementing appropriate control measures, we can mitigate its impact on agriculture and safeguard food security for millions of people worldwide.

Key words : *ULV insecticides, integrated pest management, sensitizing local.*

Introduction

The desert locust (*Schistocerca gregaria*) is a species of periodically swarming grasshopper that poses a significant threat to agriculture and livelihoods. Found mainly in Africa, Arabia, West Asia, and extending into parts of South Asia, the desert locust exhibits remarkable adaptability to environmental conditions. It undergoes a transformation from a solitary, non-migratory form to a gregarious, migratory phase, capable of traveling long distances and forming locust plagues.

During plague years, desert locusts can cause widespread damage to crops, consuming large quantities of green vegetation, including crops, pasture, and fodder. Swarms can consist of up to 150 million locusts per square kilometer and can travel up to 150 kilometers in a day. The devastation caused by even a small swarm is equivalent to the food consumption of thousands of people (Peng, 2020). As an international transboundary pest, the desert locust threatens agricultural production and livelihoods in Africa, The Middle East, and South Asia. Collaborative efforts between countries and organizations like the United Nations Food and Agriculture Organization (FAO) Desert Locust Information Service (DLIS) help monitor and mitigate locust populations.

The migratory nature and rapid population growth of desert locusts present significant challenges for control, particularly in remote semiarid areas. These locusts differ from other grasshoppers in their ability to transition from a solitary form to highly mobile adult

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swarms and hopper bands. They go through different states, including recessions, outbreaks, and plagues, with two to five generations per year. The risk of desert locust outbreaks increases with favorable weather conditions and habitat availability, leading to population upsurges and plagues.

The desert locust's ability to fly rapidly across great distances makes it the most dangerous of the locust pests. Past upsurges, such as the major event in 2004-2005, have caused significant crop losses and food insecurity in affected regions. Locust attacks in 2020, occurring in two rounds, had a devastating impact on crops in Gujarat and other areas. These swarms occur irregularly in North Africa, the Middle East, and South Asia, often following droughts followed by heavy rains. In India and Pakistan, locust swarms typically enter desert areas for breeding during the monsoon season, but in recent years, early arrivals have been observed.

Managing and controlling desert locust populations require ongoing monitoring, early detection, and coordinated efforts among affected countries. Strategies such as aerial spraying and integrated pest management techniques are employed to mitigate the impact of locust infestations. Continued research, surveillance, and international cooperation are essential in minimizing the threat of the desert locust and safeguarding agricultural productivity and food security.

Life cycle of Desert Locust :

The Desert Locust undergoes a three-stage life cycle: egg, hopper (nymph), and adult. Breeding of Desert Locusts takes place during the rainy season when the soil is moist. Female locusts lay eggs in specific conditions, usually around 5-10 cm below the soil surface, requiring sufficient moisture. They probe the soil with their abdomen to ensure the right moisture content before depositing egg pods.

The eggs are laid in batches called egg pods, resembling rice grains and arranged in clusters. These pods are typically found in areas of bare sandy soil. The number of eggs in each pod varies depending on the locust phase, with gregarious phase pods containing fewer than 80 eggs and solitarious phase pods containing between 90 and 160 eggs. During swarming events, high densities of egg pods can be observed, with numerous pods per square meter.

Female locusts bore into the ground to lay eggs and then seal the hole above the eggs with a frothy plug. The egg pods are positioned approximately 5-10 cm below the soil surface to provide protection and favorable conditions for hatching.

The eggs remain dormant in the soil until favorable environmental factors, such as temperature and moisture, stimulate their hatching. Once hatched, the nymphs emerge as hoppers and go through several instars or developmental stages before molting into the adult stage. This completes the life cycle of the Desert Locust, and the adults are capable of forming swarms and undertaking long-distance migrations.

The Desert Locust's ability to lay a large number of eggs and their adaptability to various environmental conditions contribute to population growth and the potential formation of destructive swarms. Monitoring and control measures are essential to mitigate the impact of these swarms on agriculture and food security, as locust outbreaks can cause significant damage to crops and livelihoods (Peng 2020).

Hopper : During hatching, the emerging hoppers work their way up through the froth plug to the surface. They immediately moult to the first instar. The hoppers then pass through five instars (sometimes six in the solitary phase), shedding a skin (moulting) between each. At the final moult (or fledging), the young adult (called a fledging) emerges. The hopper stages are often denoted as L1, L2, L3 and so on. The rate of hopper development, as with the rate of egg development, is a function of temperature (Simpson, 1998). Hopper populations can die from lack of food but this is unusual. Nevertheless, only a fraction of the first instar stage can die as a result of inadequate water reserves, cannibalism and predation by ants. As the remaining hoppers grow, another 10-20? may die from cannibalism, parasitism and predation.

When locusts experience crowded conditions, they undergo a phase change from solitary to gregarious behavior. In the gregarious phase, locusts form dense bands of hoppers and swarms of adults. This change is influenced by ecological conditions, successful breeding, and low natural mortality.

The modifications during the phase change include:

Behavior: Solitary locusts behave individually, while gregarious locusts form highly mobile bands and swarms.

Biology: Synchronization of mating, egg-laying, hatching, and fledging occurs in gregarious locusts.

Morphology: Changes in morphology improve the locusts' flying capacity and may alter their body color and shape.

Physiology: Gregarious females lay fewer but larger and more resistant eggs.

Grouping: Locusts form groups in open habitats with bare soil, and this grouping is an intermediate step towards gregarious behavior.

Bands: Hopper bands increase in size as hoppers develop, and nearby bands join together to form larger bands. The movement rate and cohesion of bands vary.

Adults: After fledging, adults need time for wing hardening and maturation. Maturation is stimulated by favorable conditions such as rain, and it can involve migration to suitable areas. Females mature after egg development, and males usually mature earlier. Adults can survive under harsh conditions or remain immature (Simpson, 2002).

Groups: Solitary adults change their behavior in response to the environment, concentrate in suitable areas, and form groups.

Swarms: Swarms form downwind from the breeding area, with young adults drifting away and collecting other locusts. Swarms can be low-flying sheets or high in the air, with stratiform and cumuliform formations. Swarms spread out when flying and can have high locust densities (Cabe *et al*., 2021).

These behavioral, morphological, and physiological changes contribute to the formation and dynamics of locust populations in different phases.

Locust swarms can be triggered by various factors, including :

Environmental Conditions: Locust swarms often occur in response to favorable environmental conditions such as increased rainfall and vegetation growth. Abundant food sources and suitable breeding habitats contribute to population growth and the formation of swarms (Seiji, 2012).

Breeding and Mating: Successful breeding and mating events play a crucial role in locust swarm formation. When locust populations reach a certain density, they undergo a phase change from solitary behavior to gregarious behavior, leading to the aggregation of individuals and the formation of bands and swarms.

Pheromones and Chemical Signals: Locusts release pheromones and other chemical signals that attract and synchronize the behavior of other locusts. These chemical signals can trigger aggregation and swarming behavior, as well as facilitate the coordination of feeding, mating, and migration. Crowding and Contact Stimulation: Locusts are highly sensitive to physical contact and crowding. When individuals come into close contact with each other, it can stimulate behavioral changes, including increased movement, aggregation, and the formation of swarms (Roge, 2021).

Genetic and Hormonal Factors: Genetic factors and hormonal changes within locust populations can influence their propensity to swarm. Genetic variations and specific hormonal triggers can contribute to the transition from a solitary phase to a gregarious phase, leading to swarming behavior.

Efforts by organizations like the Locust Warning Organisation (LWO) are crucial in monitoring locust populations, conducting surveys, and implementing control measures to minimize the impact of locust swarms on agriculture and the environment. By understanding the triggers and dynamics of locust swarming, effective strategies can be developed for early warning, surveillance, and targeted control interventions (Tian, 2008).

Locust management involves various strategies and approaches to control and mitigate the impact of locust populations. Here are some commonly used control measures :

1. Cultural Control: Cultivating the soil where locust eggs are laid can disrupt their development. Exposing the eggs to desiccation or predation by birds can help reduce locust populations. Collecting and destroying egg pods, known as Egg Beds, can also be effective.

2. Mechanical Control: Using mechanical means to physically remove and kill locusts. This can include catching machines to collect hoppers, followed by methods such as flame throwers or rollers to kill them. However, mechanical control is labor-intensive and challenging, particularly against large swarms.

3. Scaring Techniques: Farmers may employ methods to scare locust swarms away from their fields, such as making noise or burning tires. While these techniques can provide temporary relief, they may only shift the problem to neighboring areas, and locusts can easily return.

4. Biological Control: Utilizing natural predators and parasites of locusts to control their populations. Predatory birds, such as rose-colored and common starlings, hens, and ducks, can help reduce locust numbers. Various insects, including blister beetles, ground beetles, crickets, and certain parasitoid flies, can prey on locust eggs, nymphs, and adults.

5. Chemical Control: The use of pesticides is often employed for large-scale locust control. Spraying insecticides from helicopters or aircraft can cover vast areas and target locust swarms. However, careful consideration should be given to the selection and application of pesticides to minimize environmental impact and ensure effective control.

It's important to note that a comprehensive locust management approach typically involves a combination of these control measures, adapted to the specific situation and severity of the locust infestation. Collaboration between agricultural authorities, local communities, and international organizations is crucial for effective monitoring, early warning systems, and

Different species of Locusts reported worldwide and in India :

Locust Species	Scientific Name	Worldwide Distribution	Reported in India
Desert Locust	*Schistocerca gregaria*	Africa, Arabia, West Asia	Yes
Migratory Locust	*Locusta migratoria manilensis* Locusta migratoria migratorioides	Asia, Europe, Africa	Yes
Moroccan Locust	*Dociostarus moroccanus*	North Africa, Middle East	No
Italian Locust	*Calliptamus italicus*	Europe, Asia	No
Brown Locust	*Locustana pardalina*	Africa	No
Australian Locust	*Chortoicetes terminifera*	Australia	No
Red Locust	*Nomadacris septemfasciata*	Africa	No
South American Locust	*Schistocera paranensis*	South America	No
Tree Locust	*Anacridium melanorhodon*	Africa, Asia	Yes
Bombay Locust (Indian Locust)	*Nomadacris succincta*	South Asia	Yes

Desert Locust

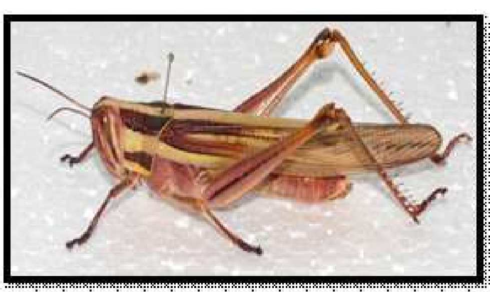
Migratory Locust

Moroccan Locust

Italian Locust

Brown Locust

Australian Locust



Red Locust

South American Locust

Tree Locust

Bombay Locust

Difference between Locust and Grasshoppers :

Locust	Grasshopper
Short horned and short hind legs.	Not a type of locust. Long horned and large hind legs.
Order : Orthoptera	Order : Orthoptera
Suborder : Caelifera	Suborder : Caelifera
Only one family in Locust.	It contains 28 distinct families.
Two different behavioural states which are solitary and gregarious.	They lack behavioural state as that of locust.
They have dense swarms.	They don't have any such swarms.

coordinated response efforts to minimize the damage caused by locust swarms.

Integrated Pest Management (IPM) practices aim to manage locust populations effectively while minimizing the environmental impact and ensuring sustainable agricultural practices. Here are some IPM practices commonly used for locust management:

Baiting: Mixing insecticide dust, such as Malathion 5% DP or Fenvalerate 0.4% DP, with a carrier like maize meal or wheat bran, and scattering the mixture among or in the path of the locusts. This method is used for marching bands, settled hoppers, and adults. Care should be taken to ensure livestock do not consume the bait.

Mechanical Control: Implementing mechanical methods to control locusts, such as digging trenches dusted with insecticides like Malathion 5% DP for hoppers to fall into or beating hoppers with branches.

Aerial Spraying: Using ultra-low volume (ULV) insecticides, like Malathion 96%, for aerial spraying under the supervision of government authorities. This is typically done during evening or night hours when swarms settle on vegetation.

Neem-based Insecticides: Spraying crops with neem-based insecticides containing Azadirachtin 1500 ppm, mixed with a spreading agent like soap solution, as a prophylactic measure (Sharma 2014).

Entomopathogenic Fungi: Spraying crops with the entomopathogenic fungus Metarhizium anisopliae (strain IMI 330189) to target locusts. The fungus is applied in an oil formulation.

Sound and Smoke Techniques: Creating sound using beating plates or generating a cloud of smoke by burning refuse to deter locusts from settling in cultivated areas.

Biological Control: Utilizing natural predators like ducks, which can consume a significant number of locusts per day, to counter locust attacks.

Selective Pesticide Application: Applying foliar sprays of specific chemical pesticides like lambda cyhalothrin 5EC or fipronil 5SC on crops such as moong (mung bean) to target locusts while minimizing impacts on non-target organisms.

Drone-Based Spraying: Employing drones equipped with chemical pesticides like Malathion for aerial sprays, offering more precise and targeted application.

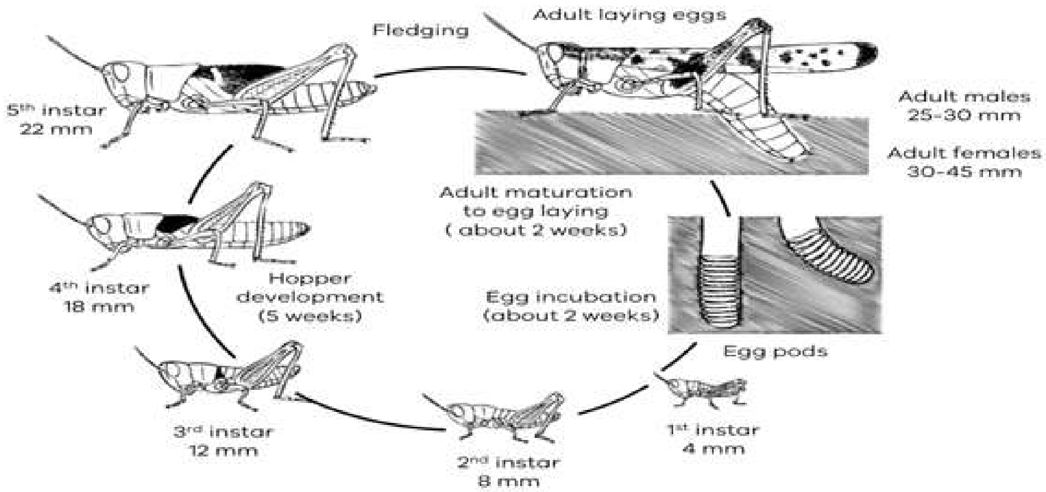
These IPM practices demonstrate a comprehensive approach that combines various methods to control locust populations effectively. It is important to adapt these practices to local conditions and collaborate with government authorities, agricultural experts, and local communities for optimal locust management.

Case Study : Desert Locust Plague Monitoring Using Time Series Satellite Data

Researchers Geng Y., Dong Y.Y., Zhao L.L., Huang W.J., Ruan C., Zhang H.S., and Zhang B.Y. conducted a study to monitor desert locust plague using time series satellite data. The study focused on six countries heavily affected by locust damage, namely India, Pakistan, Ethiopia, Kenya, Somalia, and Yemen. Remote sensing data, specifically MODIS (Moderate Resolution Imaging Spectroradiometer), was utilized to obtain vegetation coverage curves in these countries from February 2000 to June 2020.

Results

The study monitored locust damage by analyzing



S. No.	Name of pesticides	a.i.(gms)/ha	Formulaions (gm/ml) ha
1.	Chloropyriphos 20% EC	240	1200
2.	Chloropyriphos 50% EC	240	500
3.	Deltamethrin 2.8% EC	12.5	500
4.	Deltamethrin 1.25% ulv	12.5	1000
5.	Diflubenzuron 25% WP	60*	240
6.	Fipronil 5% SC	6.25	125
7.	Fipronil 2.92% EC	6.25	220
8.	Lamdacyhalothrin 5% EC	20	400
9.	Lamdacyhalothrin 10% WP	20	200
10.	Malathion 50% EC	925	1850
11.	Malathion 25% WP	925	3700

changes in vegetation using MODIS remote sensing data. The results indicated that desert locusts caused significant harm to vegetation. By the end of June 2020, the areas of vegetation affected by desert locusts were as follows: India (1058.3 thousand hectares), Pakistan (792.9 thousand hectares), Ethiopia (1137.5 thousand hectares), Kenya (936.8 thousand hectares), Somalia (780 thousand hectares), and Yemen (763.5 thousand hectares). These research findings laid the groundwork for real-time, rapid, and large-scale monitoring of locust plague dynamics, and provided a scientific basis for implementing effective and economical locust prevention measures.

Future Prospects

1. Farmer Awareness: Raising awareness among farmers about locusts and effective population control measures to safeguard their crops.

2. Government Support: Governments should declare locust attacks as national and international disasters and provide compensation to affected farmers.

3. Collaborative Efforts: States, countries, and agricultural authorities should take significant steps to control the spread of locusts through coordinated actions.

4. Evaluation of New Pesticides: Assessment and promotion of new chemical pesticides with low mammalian toxicity for locust control.

5. Innovative Control Methods: Implementation of new and effective methods for locust control to combat infestations.

Conclusions

Locusts are highly destructive pests in agriculture, recognized as one of the most dangerous migratory species due to their rapid reproduction, long-distance migration, and capacity to devastate crops. Climate change plays a significant role in the spreading and severity of locust attacks.

During their gregarious phases, locusts invade various regions and cause adverse effects on vegetation.

Biological control measures, such as using chickens and ducks, can be employed to manage locust populations.

Chemical pesticides like Malathion 50% EC, Deltamethrin 2.8% EC, and Fipronil 5% SC can be utilized for locust control.

Advanced technologies, including drones, can be harnessed for the monitoring and management of locust populations, offering enhanced efficiency and effectiveness in locust control efforts.

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Chapter 5

Importance of Food Legumes in Indian Agriculture and Their Global Production

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India is a major producer of food legumes, and some of the major food legumes grown in the country include chickpea (also known as gram), lentil, pigeon pea (also known as arhar or toor), mung bean, black gram (also known as urad), and cowpea (also known as chawli or lobia). Here's a breakdown of the share, production, and productivity of these major food legumes in India :

Chickpea : Chickpea is one of the most important food legumes grown in India, accounting for approximately 39% of total food legume production in the country. In 2020-21, India produced 11.81 million tonnes of chickpea, with an average productivity of 777 kg per hectare.

Lentil : Lentil is another important food legume grown in India, accounting for approximately 8% of total food legume production in the country. In 2020-21, India produced 1.64 million tonnes of lentil, with an average productivity of 679 kg per hectare.

Pigeon pea : Pigeon pea is one of the most widely cultivated food legumes in India, accounting for approximately 24% of total food legume production in the country. In 2020-21, India produced 7.05 million tonnes of pigeon pea, with an average productivity of 838 kg per hectare.

Mung bean : Mung bean is another important food legume grown in India, accounting for approximately 7% of total food legume production in the country. In 2020-21, India produced 2.08 million tonnes of mung bean, with an average productivity of 612 kg per hectare.

Black gram : Black gram is another significant food legume grown in India, accounting for approximately 14% of total food legume production in the country. In 2020-21, India produced 4.20 million tonnes of black gram, with an average productivity of 614 kg per hectare.

Cowpea : Cowpea is also an important food legume grown in India, accounting for approximately 7% of total food legume production in the country. In 2020-21, India produced 2.20 million tonnes of cowpea, with an average productivity of 531 kg per hectare.

Overall, these major food legumes play a crucial role in Indian agriculture and are an important source of nutrition for the population.

Why pulses are considered beneficial? : Here's a brief explanation for each point :

1. Rich in protein (average 20-30%) : Pulses are an excellent source of plant-based protein, making them a great food choice for vegetarians and vegans or for those who want to reduce their meat consumption.

2. Fix both atmospheric nitrogen (~ 40 kg/ha) and carbon : Pulses have the ability to form a symbiotic relationship with soil bacteria, which allows them to convert atmospheric nitrogen into a form that plants can use. This process is known as nitrogen fixation, and it helps to enrich the soil with nutrients without the need for synthetic fertilizers.

3. Require less water than other crops and save 2-3 irrigations : Pulses are known to have a relatively low water requirement compared to other crops, which makes them a great choice for areas with limited water resources. Additionally, their deep root systems help them to access water from deeper in the soil, further reducing their water requirements.

Cited as : Singh S.P. (2023). ICAAAS : An initiative towards sustainable agriculture and allied sciences. *ICAAAS–An Edited Book.* Volume-2 : 39-45. Astha Foundation, Meerut (U.P.) India.

4. Greater adaptability due to inherent ability for drought tolerance : Pulses have evolved to thrive in environments with varying levels of moisture and rainfall, making them a great choice for areas with erratic weather patterns or drought-prone regions.

5. Ability to modify with dynamic changes of the environment : Pulses are adaptable to changes in the environment, such as variations in temperature, humidity, and soil quality. This allows them to continue growing and producing a crop even when conditions are less than ideal.

6. Environment friendly : As a crop, pulses are environmentally friendly because they have a low carbon footprint, require less water and synthetic fertilizers compared to other crops, and improve soil quality through nitrogen fixation.

In summary, pulses are considered beneficial because they are rich in protein, fix atmospheric nitrogen, require less water, have inherent drought tolerance, adapt well to changing environments, and are environmentally friendly.

Major food legume producing countries in the world for the year 2020-21 (in metric tonnes, unless otherwise specified) :

1. India - 23,000,000
2. Myanmar - 5,000,000
3. Canada - 4,200,000
4. China - 3,500,000
5. United States - 2,800,000
6. Brazil - 2,700,000
7. Australia - 1,500,000
8. Ethiopia - 1,300,000
9. Russia - 1,100,000
10. Mexico - 980,000

Note that these rankings can vary depending on the year and the specific legume being considered. Also, these numbers are approximate and subject to change due to factors such as weather, market demand, and trade policies.

Major food legumes and the percentage share of different countries in global pulse production:

Chickpeas : India (67%), Pakistan (8%), Turkey (4%), Australia (4%), Iran (3%), Ethiopia (2%), Canada (2%)

Lentils : Canada (38%), India (18%), Turkey (11%), Australia (10%), United States (4%), Nepal (3%)

Dry beans : Brazil (32%), India (16%), China (12%), Myanmar (6%), United States (5%), Mexico (4%), Tanzania (3%)

Peas : China (40%), Canada (15%), Russia (7%), India (6%), United States (4%), France (3%).

Note : that these percentages are approximate and may vary depending on the year and specific data source used.

Latest figures for the area, production, and yield of pulses in India :

Area : According to the Agriculture Ministry of India, the total area under pulses cultivation in India during the 2020-21 crop year was 26.30 million hectares.

Production : The total production of pulses in India during the 2020-21 crop year was 23.01 million tonnes, according to the Ministry of Agriculture.

Yield : The average yield of pulses in India during the 2020-21 crop year was 877 kg per hectare.

Note : that pulses are an important source of protein for the Indian population, and the government has been taking various steps to promote their cultivation and increase their production. However, the productivity of pulses in India is still relatively low compared to other major pulse-producing countries, and efforts are being made to address this issue through measures such as the promotion of improved varieties, better farming practices, and increased government support.

Constraints in pulses production in India and Bihar:

Low productivity : One of the major constraints in pulses production in India is low productivity. This is due to a variety of factors, including poor soil fertility, lack of access to improved seeds and fertilizers, and inadequate irrigation facilities.

Climate variability : Pulse crops are highly sensitive to weather conditions, and climate variability can have a significant impact on their productivity. Erratic rainfall, extreme temperatures, and frequent droughts can all affect pulse yields.

Pests and diseases : Pulse crops are also vulnerable to a range of pests and diseases, which can cause significant yield losses if not properly managed. Common pests and diseases in pulse crops include pod borers, aphids, wilt, and root rot.

Limited market access : Another constraint in pulses production is limited market access, particularly for small-scale farmers. Many farmers are not able to access profitable markets for their produce, which can discourage them from growing pulses.

Lack of credit and insurance : Small-scale pulse farmers often face challenges in accessing credit and insurance services, which can limit their ability to invest in inputs and technologies that can improve their productivity and resilience.

In Bihar, some additional constraints in pulses production include the low availability of irrigation facilities, poor soil quality, and the prevalence of pests and diseases. However, the government of Bihar has launched several initiatives to address these challenges, including the promotion of improved varieties, better farming practices, and increased access to credit and insurance services for farmers.

Instability in Production : This refers to the unpredictable nature of the production output of pulses, which could be caused by several factors such as weather conditions, pests, and diseases.

Being rainfed crop, pulses experience drought at critical growth stages : Pulses are grown under rain-fed conditions, meaning that they rely on natural rainfall for their growth. However, during critical growth stages, such as flowering and pod formation, if there is a shortage of rainfall, it can lead to drought stress and affect the yield.

Highly sensitive to abiotic stresses (temperature extremities, excessive moisture and salinity) : Pulses are sensitive to changes in environmental conditions, such as temperature extremes, excess moisture, and high salinity in the soil. These factors can affect their growth and yield.

Vulnerable to a large number of diseases : Pulses are susceptible to a range of diseases, which can significantly reduce their yield. Common diseases that affect pulses include rust, blight, and wilt.

Infestation with several insect-pests : Pulses are also vulnerable to insect pests, such as aphids, thrips, and pod borers. These pests can cause significant damage to the crop and reduce its yield.

Climate change : Climate change has a significant impact on the growth and productivity of pulses. Changes in temperature and rainfall patterns can affect the yield of pulses.

High night temperature adversely affect productivity of winter pulses : High night temperatures during the winter season can negatively impact the productivity of winter pulses, such as chickpea and lentil.

Drought situation appears in more severe form as a result of high temperature interaction : Drought stress in pulses can be exacerbated by high temperatures, which can further reduce the yield.

Expected changes in the native flora of Rhizobium and other useful microbes due to ecological imbalances : Rhizobium and other beneficial microbes play a crucial role in fixing atmospheric nitrogen in the soil, which is essential for the growth of pulses. Ecological imbalances can affect the population and diversity of these microbes, which can impact the productivity of pulses.

Several government programs for pulses' development in India since 1970 : Here are some of the significant initiatives :

National Pulses Development Programme: Launched in 1970, this program aimed to increase the production and productivity of pulses in the country. The program provided financial assistance to farmers for promoting the cultivation of pulses and the adoption of modern technologies.

Technology Mission on Pulses (TMP): Launched in 1986-87, the Technology Mission on Pulses aimed to increase the productivity of pulses through the adoption of new technologies, improved seed varieties, and better farming practices. The program also focused on increasing the production of protein-rich pulses to meet the country's nutritional requirements.

Frontline Demonstrations Project on Pulses: Launched in 1989, this project aimed to demonstrate the performance of new technologies and varieties of pulses to farmers. Under this project, selected farmers were provided with seeds, fertilizers, and other inputs to cultivate new varieties of pulses.

National Food Security Mission: Launched in 2007, this mission aimed to increase the production of rice, wheat, and pulses. Under this program, farmers were provided with improved seeds, fertilizers, and other inputs. The mission has been successful in increasing the production of pulses in the country.

Mini-kits on Pulses Project : Launched in 2016, this project aimed to provide small kits containing seeds, fertilizers, and other inputs for cultivating pulses to farmers. The project aimed to promote the adoption of modern technologies and practices among farmers.

National Food Security Mission (NFSM) : Launched in 2007, the National Food Security Mission aimed to increase the production of pulses and other food crops to achieve food security in the country. The program provided financial support to farmers for the adoption of new technologies, improved seed varieties, and better farm practices.

➢**Rashtriya Krishi Vikas Yojana (RKVY) :** Launched in 2007, the Rashtriya Krishi Vikas Yojana aimed to provide financial support to farmers for the adoption of new technologies, improved seed varieties, and better farm practices. The program also aimed to increase the production of pulses and other food crops to achieve food security.

National Mission on Sustainable Agriculture (NMSA) : Launched in 2010, the National Mission on Sustainable Agriculture aimed to promote sustainable agriculture practices, including the cultivation of pulses. The program provided financial support to farmers for the adoption of new technologies, improved seed varieties, and better farm practices.

➢**Accelerated Pulses Production Programme :** Launched in 2010, this program aimed to increase the production of pulses by providing financial assistance to farmers for promoting the adoption of modern technologies and practices.

➢**Additional BS Production Project :** Launched in 2011, this project aimed to increase the production of black gram (urad) and green gram (moong) by promoting the adoption of new technologies and varieties of these crops.

Integrated Scheme for Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) : Launched in 2011, the Integrated Scheme for Oilseeds, Pulses, Oil Palm and Maize aimed to increase the production of oilseeds, pulses, oil palm, and maize through the adoption of new technologies, improved seed varieties, and better farm practices. The program also provided financial support to farmers for the cultivation of these crops.

Seed-hubs of Pulses Project : Launched in 2016, this project aimed to establish seed hubs for producing quality seeds of pulses. The project aimed to increase the availability of quality seeds of pulses to farmers.

Cluster Frontline Demonstration Project : Launched in 2016, this project aimed to demonstrate the performance of new technologies and varieties of pulses in specific clusters of villages. The project aimed to promote the adoption of these technologies and varieties among farmers.

Price Stabilization Fund Scheme : Launched in 2016, this scheme aimed to provide financial assistance to states for the procurement of pulses at the minimum support price (MSP) and for the creation of buffer stocks to stabilize prices.

Pradhan Mantri Fasal Bima Yojana (PMFBY): Launched in 2016, this program aims to provide crop insurance to farmers. The program covers several crops, including pulses. The aim of the program is to protect farmers from crop losses due to natural calamities or other unforeseen events.

These are some of the notable government programs for pulses' development since 1970. These programs have played a significant role in increasing the production of pulses in the country and promoting the adoption of modern technologies among farmers.

The General plant ideotype in pulses refers to an ideal plant architecture that would allow for optimal growth and yield in pulse crops such as beans, lentils, chickpeas, and peas. The general plant ideotype is a set of traits and characteristics that researchers and breeders aim to develop in pulses for better performance in terms of yield, quality, and disease resistance.

The key traits of the general plant ideotype in pulses include :

Shorter stature: Pulse plants with shorter stature tend to have stronger stems and require less input for growth, which can lead to higher yields.

Branching habit: Pulse plants with a more branching habit tend to have more nodes and flowers, which can result in increased yield.

Early maturity: Early-maturing pulse plants tend to have more time to grow and develop, which can lead to higher yield and better quality.

Resistance to biotic and abiotic stresses: Pulse plants with resistance to diseases, pests, and environmental stressors are more likely to survive and produce higher yields.

Efficient nutrient use: Pulse plants that are efficient in their use of nutrients can produce higher yields with less fertilizer input.

By breeding or developing pulse varieties with these traits, researchers and breeders aim to improve the overall productivity and sustainability of pulse farming. The general plant ideotype in pulses serves as a guide for developing improved varieties that are well-suited for different growing conditions and can help to meet the increasing demand for pulses globally.

Pulses, such as beans, lentils, chickpeas, and peas, have a narrow genetic base, meaning that there is limited genetic diversity within the crop. This is because domestication and modern breeding practices have reduced the number of genes that are present in the crop, leading to a loss of genetic variation.

Widening the genetic base of pulses is important because it can help to increase the crop's resilience to environmental stresses, such as drought, disease, and pests. To do this, pre-breeding techniques are used, which involve introducing new genetic material from exotic, landraces, and wild species into the domesticated crop.

By incorporating genetic diversity from these other sources, pre-breeding can create new variations of the crop that are better adapted to different environments, have improved yield potential, and increased resistance to biotic and abiotic stressors. This can ultimately lead to the development of new varieties that are more productive and sustainable.

Overall, widening the genetic base of pulses is a crucial step in improving the crop's genetic diversity and resilience, and pre-breeding techniques are an important tool for achieving this goal.

Genetic enhancement for yield and quality in pulses is an important area of research and development to ensure that the crop can meet the growing demand for plant-based protein in the world. There are several strategies that can be used to improve the yield and quality of pulses, including the use of genetic resources, wider adaptation, conventional breeding, and bio-fortification.

Vast genetic resources should be used for the development of new plant types that are better adapted to different agro-climatic zones. This is because wider adaptation is rare in pulses, and most of the crops are locally adapted. Therefore, by using genetic resources from different sources, new varieties of pulses can be developed that are better adapted to different environments, which can help to improve the yield and quality of the crop.

Conventional breeding is also an important strategy for genetic enhancement of pulses. It should be focused on the development of high-yielding varieties with wider adaptation, while minimizing the presence of anti-nutritional factors and enhancing the nutritive values of pulses. For example, breeding programs can be directed towards developing pulses that have higher protein content, improved amino acid profiles, and reduced levels of anti-nutritional factors.

Bio-fortification is another important strategy for enhancing the quality of pulses. This involves increasing the levels of key nutrients such as iron and zinc in the crop through plant breeding. Bio-fortification can also be used to increase the bioavailability of these nutrients in specific pulses, making them more effective in improving human health.

Finally, efforts can be made to increase the levels of sulphur-rich amino acids, such as methionine and cysteine, in pulse grains. This can be achieved through breeding programs or genetic engineering approaches, and can help to improve the nutritional quality of pulses and make them more valuable as a source of protein in human diets.

In summary, genetic enhancement for yield and quality in pulses involves a range of strategies, including the use of genetic resources, conventional breeding, bio-fortification, and efforts to increase the levels of key nutrients and amino acids in pulse grains. These strategies can help to improve the sustainability and nutritional value of pulses, and ensure that they can play an important role in meeting the food needs of a growing global population.

Enhancing pulse productivity

Enhancing pulse productivity is an important goal for agriculture, given the increasing demand for plant-based protein and the need to improve the sustainability of food production. There are several thrust areas for enhancing pulse productivity, including:

Breeding for high-yielding varieties: Developing new varieties of pulses that have high yield potential is an important thrust area. This can be achieved through traditional breeding methods or through genetic engineering.

Improving stress tolerance: Pulses are often grown in marginal lands and can be subject to various environmental stresses, such as drought, heat, and salinity. Breeding for stress tolerance can help to improve the resilience of pulse crops to these stresses.

Reducing input costs: The high cost of inputs, such as fertilizers and pesticides, can be a significant barrier to improving pulse productivity. Developing varieties that require less inputs or are resistant to pests and diseases can help to reduce input costs and improve productivity.

Improving nutrient-use efficiency: Enhancing the efficiency with which pulses use nutrients, such as nitrogen and phosphorus, can help to reduce fertilizer use and improve productivity.

Improving market access: Improving market access for pulse farmers can help to increase the profitability of pulse cultivation and provide incentives for farmers to invest in improving productivity.

Enhancing soil health: Healthy soils are essential for productive agriculture. Strategies to improve soil health, such as crop rotations, cover cropping, and conservation tillage, can help to improve pulse productivity.

Mechanization and precision farming: Mechanization and precision farming technologies can help to reduce labor costs and improve the efficiency of pulse cultivation.

These are different research areas or objectives related to agricultural development. Here's a brief explanation of each one :

Development of extra-early photo-thermo insensitive vars. for diversification of cereal-based cropping systems: This refers to the development of plant varieties that can grow and mature quickly, regardless of day length or temperature fluctuations. This can help farmers diversify their crops and reduce the risk of crop failure due to weather changes.

Development of ideal plant types of chickpea under rainfed condition: This refers to the development of plant varieties of chickpea that are well-adapted to growing conditions with limited rainfall. The goal is to increase the yield and quality of chickpea crops, which is an important food crop in many regions.

Genetic enhancement of yield, quality, and resistance to biotic and abiotic stresses: This involves the use of genetic techniques to improve crop performance by increasing yield, improving quality, and enhancing resistance to pests and diseases as well as environmental stresses such as drought or high temperatures.

Mapping and tagging of genes/QTLs and MAS for desirable traits: This refers to the identification and mapping of specific genes or genetic regions that are associated with desirable traits such as high yield or disease resistance. This information can be used to develop markers that can be used in breeding programs to select for these traits more efficiently.

Development of transgenics in chickpea: This involves the use of genetic engineering techniques to introduce desirable traits into chickpea plants. This could include traits such as enhanced disease resistance, improved nutrient uptake, or increased tolerance to environmental stresses.

Development of effective and eco-friendly IPM modules for major pests: IPM stands for Integrated Pest Management, which is an approach to pest control that combines multiple methods to reduce the use of pesticides and minimize environmental damage. This objective involves developing effective and environmentally-friendly methods for controlling major pests in crops.

Dissemination of pulse production technologies through farmer participatory approach for improving the livelihood of rural masses: This involves working with farmers to develop and implement technologies and practices that can increase the production of pulse crops (such as lentils, beans, and chickpeas) and improve the livelihoods of rural communities. This approach is participatory, meaning that farmers are involved in the research and development process.

In conclusion, enhancing pulse productivity requires a multifaceted approach that involves a combination of breeding, agronomic, and market-based strategies. By focusing on these thrust areas, it is possible to increase the productivity of pulse crops, improve the sustainability of food production, and meet the growing demand for plant-based protein.

Strategies to enhance pulses productivity in India

There are several strategies that can be implemented to enhance pulses productivity in India. Here are a few examples :

Improving seed quality: The use of high-quality seeds can significantly improve pulse productivity. This can be achieved through the development of improved varieties, the use of certified seeds, and the promotion of seed treatment and storage practices.

Promoting balanced use of fertilizers: The application of balanced fertilizers can help improve soil fertility and enhance pulse productivity. The use of organic and bio-fertilizers can also be encouraged to reduce the reliance on chemical fertilizers.

Adopting improved cropping practices: The adoption of practices such as intercropping, crop rotation, and conservation agriculture can help improve soil health and reduce pest and disease pressure, leading to increased productivity.

Increasing access to credit: Access to credit can help farmers purchase high-quality inputs, adopt new technologies, and expand their farming operations. This can be achieved through the provision of formal credit, as well as the promotion of community-based credit systems.

Strengthening research and extension services: Research and extension services can provide farmers with the latest information and technologies for enhancing pulse productivity. This can be achieved through the establishment of research centers, the development of extension programs, and the training of extension workers.

Encouraging private sector investment: Private sector investment can help spur innovation and increase access to markets and technologies. This can be achieved through the development of public-private partnerships and the provision of incentives for private sector investment in the pulse sector.

Providing better market access: Improved market access can help farmers obtain better prices for their pulses, which can increase their profitability and incentivize further investment in pulse production. This can be achieved through the development of market infrastructure, the promotion of value-addition activities, and the establishment of linkages between farmers and buyers.

Strategies to achieve Self-sufficiency in pulse production

Self-sufficiency in pulse production can be achieved through various strategies such as :

Crop rotation : This involves the alternating of pulse crops with other crops to break the disease cycle and improve soil fertility. Legumes such as soybeans, peas, and lentils are ideal for rotation with other crops.

Improved varieties : The use of improved varieties of pulses with high yield potential, disease resistance, and drought tolerance can increase productivity and enhance self-sufficiency.

Efficient water management: Proper water management through irrigation scheduling, efficient use of water resources, and rainwater harvesting can improve pulse production and reduce dependence on external sources of water.

Integrated pest management : This involves the use of natural enemies and beneficial insects to control pests and reduce the use of synthetic pesticides, which can be expensive and harmful to the environment.

Organic farming : Organic farming practices such as the use of organic fertilizers, crop rotation, and biological pest control can improve soil health, reduce the use of synthetic inputs, and enhance self-sufficiency.

Post-harvest management: Proper post-harvest management practices such as storage, drying, and processing can reduce post-harvest losses and improve the quality of pulses.

Farmer capacity building: Providing training and extension services to farmers on pulse production, marketing, and value addition can enhance their skills and knowledge, and improve self-sufficiency.

In conclusion, Pulses are considered beneficial because they are a good source of plant-based protein, fiber, and other nutrients. Major food legume producing countries in the world in 2020-21 include India, Canada, Myanmar, and Brazil. India is the largest producer and consumer of pulses, accounting for a significant percentage of global pulse production. Constraints in pulses production in India and Bihar include low productivity, poor soil fertility, pest and disease problems, and inadequate infrastructure.

The Indian government has implemented several programs for pulses' development since 1970 to address these constraints and increase production. The key traits of the general plant ideotype in pulses include early maturity, high yield potential, and resistance to biotic and abiotic stresses. Strategies to enhance pulse productivity in India include developing high-yielding varieties, improving soil fertility and management practices, and promoting mechanization. Strategies to achieve self-sufficiency in pulse production in India include increasing area under cultivation, reducing imports, and promoting value addition and export.

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Chapter 6

Strategies for Crop Regulation in Guava

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Guava (*Psidium guajava* L.; 2n=2x=22; family Myrtaceae) is a wholesome tropical fruit packed with the goodness of dietary fiber, pectin, vitamins (ascorbic acid, thiamine, riboflavin, and niacin), minerals (potassium, phosphorus, calcium, and iron) and antioxidants (polyphenols, lycopene, carotenoids, lutein, and cryptoxanthin. It is considered one of the highly remunerative fruit crops because of its precocious and prolific bearing habit and its ability to give satisfactory yield without much care under various biotic and abiotic stresses. It is native to tropical America stretching from Mexico to Peru and has been naturalized in many countries owing to its hardy nature and wide edaphoclimatic adaptability, such as India where it was introduced by the Portuguese in the 17th century. Since its introduction, the extent of popularity and prominence it has acquired in Indian horticulture is remarkable. It is cultivated throughout the tropical and sub-tropical regions of the country for fresh consumption as well as for processing into jam, jelly, juice, nectar, cheese, squash, leather, and puree. With an annual production of 4.05 million tonnes from a cultivated area of 2.65 lakh hectares, guava is the 5th most extensively cultivated fruit crop in India after mango, citrus, banana, and apple (2017-18). Uttar Pradesh, Madhya Pradesh, Bihar, Chhattisgarh, West Bengal, Odisha, Gujarat, and Haryana are the key guava-growing states in the country.

Depending on the climate of the growing area, guava blooms twice or thrice a year during the spring, rainy, and autumn seasons, known as *Ambe, Mrig*, and *Hasta Bahar*, respectively. *Ambe Bahar* is intense because after a period of rest and reserving food during winter, the guava plant resumes its growth during spring with vigour and it yields a heavy crop during the rainy season (July-October). Whereas *Mrig* and *Hasta Bahar* are sparse and produce a light crop during winter (December-January) and spring-summer (March-May), respectively, as food reserves are already depleted by *Ambe Bahar* in the process of flushing, flowering, and fruiting. Recurrent flowering and fruiting exhaust the plant because it does not get sufficient rest to replenish its food reserves resulting in a suboptimal harvest of substandard quality almost throughout the year. Fruit quality is also influenced by various climatic parameters, particularly temperature and humidity. Low temperature and dry atmospheric conditions favour the proper development of sweetness, color, and aroma in the fruits. Since humidity and temperature are high during the rainy season, guava crop maturing during this season is insipid and poor in quality. Besides, the rainy crop has the problem of fruit fly and anthracnose disease making it unfit for human consumption and marketing. On the other hand, the winter harvest is superior in quality and fetches better market price as compared to the rainy crop on account of great demand in the market. Better post-harvest life of winter produce allows its transportation to distant markets offering better market opportunities over the rainy crop. Salient features of guava flowering (*Bahar*) are given below :

Bahar	Flowering season	Fruit maturity season	Yield share (%)	Fruit quality
Ambe	Spring	Rainy	70-75	Average
Mrig	Rainy	Winter	20-25	Very good
Hasta	Autumn	Spring-Summer	5-10	Good

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Considering the flowering and fruiting behaviour of guava and market preference, subject matter experts/ scientists/researchers are advocating commercial guava growers to take one crop every year, ideally a winter crop on account of better quality and less incidence of fruit fly infestation and diseases. The practice of taking one crop in a year is a very practical and efficient strategy for realizing higher monetary returns from guava orcharding as it ensures a bumper and quality harvest in desired season and keeps the orchard productive and profitable for a long. Therefore, it is essential to regulate or manipulate the natural flowering tendency of guava towards the induction of profuse flowering during the desired season, i.e., *Mrig Bahar*. The practice of forcing a guava plant to flower and fruit profusely during the desired season is termed crop or *Bahar* regulation. It is considered one of the most critical aspects of guava orcharding as it makes the production system more sustainable, profitable, and consumer-centric. For crop regulation, a guava plant is made to rest during the undesirable season of flowering by imposing certain stress-inducing treatments known as *Bahar* treatment so that it can flower and bear heavily during the desirable season.

Principle of crop regulation

The concept of crop regulation in guava is based on its bearing habit. Guava bears flowers on new shoots/ flushes irrespective of the time of year. New shoots are produced on mature wood or past season's growth laterally or terminally (Fig. 1). In general, flowers are produced in the axils of leaves as solitary or in cymes of two or three flowers. Sometimes, flowers appear at the tip of the current season's growth. Thus, crop load depends upon the number of new shoots. The emergence of more lateral shoots on a branch means more flowering and fruiting. Upright/erect growing branches produce new lateral shoots near their top end. The lower buds of such branches remain dormant because of the apical dominance phenomenon. The tip of the branches produces a plant hormone known as auxin that moves downwards and inhibits the growth and development of lateral buds. This suppressive effect of auxin on lateral buds gets diluted in spreading, droopy, or horizontally growing branches, and such branches produce an enormous number of new lateral shoots. Production of flowers on new shoots is determined by the food reserves of a plant. For flowering, a plant should have sufficient carbohydrate reserves, i.e., a high C: N ratio. Thus, heavy flowering during the rainy season (*Mrig Bahar*) could be induced by meeting these two prerequisites, i.e., induction of abundant flushing during summer and elimination or reduction of the rainy crop.

Methods of crop regulation

Various strategies could be employed to full fill the pre-requisites of *Mrig Bahar*, viz., shoot pruning, branch bending, application of abscission-inducing chemicals (defoliants, flower thinners), imposing stress by withholding irrigation, exposing roots, and pruning roots.

1. Shoot pruning

Guava is a pruning-responsive crop as it bears flowers on new shoots. Pruning guava plants annually is considered one of the cheapest and most effective cultural techniques for reducing rainy crop load and enhancing the share of the winter harvest. For the induction of *Mrig Bahar,* the shoots should be pruned during summer (April-May) at an appropriate severity which may range from 30-70% depending upon plant growth and agroclimatic conditions. Pruning affects the biosynthesis of auxin negatively due to the removal of the shoot tip which in turn leads to the activation/ invigoration of latent buds present on the shoots culminating in the emergence of new laterals or shoots (Fig. 2). Since the response of guava to pruning varies, it is wise not to follow the pruning recommendation of one region blindly in other areas having entirely different agroclimatic conditions. In a crop regulation study carried out at ICAR-IIHR- Central Horticultural Experiment Station, Bhubaneswar, summer shoot pruning which has been reported as one of the effective tools for shifting the rainy harvest to the winter in various parts of the country, particularly in North India, was found ineffective under the hot and humid climate of Odisha. Despite having a significant influence on flush production, summer pruning failed to enhance the flowering during the rainy season (*Mrig Bahar*) on

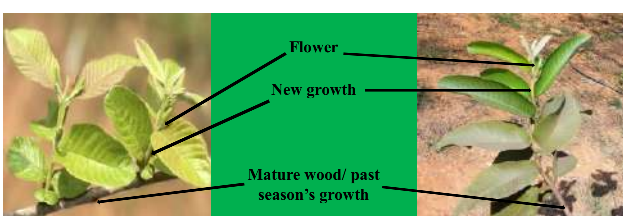

Fig.-1 : Flowering behaviour of guava.

Fig.-2 : Influence of pruning on lateral shoot production and flowering

account of the vigorous nature of the new flush favoured by the prevailing hot and humid climate. Under the influence of vigorous growth, the buds present in the leaf axil of new laterals give rise to vegetative growth primarily instead of flowers. However, winter pruning at 70% intensity was found effective to enhance the quantum and quality of the rainy crop. Therefore, Location-specific standardization of pruning in terms of time and severity is essential before adopting this practice as a tool of crop regulation on a commercial scale.

2. Branch bending

It is one of the simple canopy architecture manipulation strategies to intensify the off-season flowering and fruiting in guava by stimulating the new shoot/lateral production and keeping their vigour under check. It is an indigenous technical knowledge (ITK) commercially practiced in a few pockets of West Bengal to promote off-season flowering (*Mrig Bahar*) and fruiting (winter crop) in guava. It can easily be followed in low-density orchards with wider spacing (5m x 5m) from the age of 2 to 12 years of age, depending upon the climate and cultivars. In the case of an old plantation with difficult-to-bend branches, it is suggested to develop a fresh canopy of flexible branches by heading back the plants to the secondary branch level. Details of this ITK are given below-

❖ **How to practice?**

Thin out small, dried, dead, and diseased shoots and branches. Remove all the leaves, flowers, and developing fruits by hand after keeping 10-15 pairs of leaves at the apex of the branches. Thereafter, bend the branches towards the ground by exerting pressure gradually from the proximal end of the branch to the distal end. Keep the branches in the bent position by tying the tips of branches to the pegs fixed to the ground with the help of rope (Fig. 3). New shoots will appear on these bent branches after 10-20 days of bending and the flushing will continue for about another 20-25 days. Untie the bent branches once flushing is completed (40-45 days after bending).

❖ **What is the suitable time for branch bending?**

It should preferably be done in May to get the winter crop, as it takes around six and a half to seven months to get a guava harvest after practicing branch bending.

❖ **How does branch bending work?**

The change in the orientation of branches to the ground induces abundant flushing, flowering, and fruiting (Fig. 3), as well as improves fruit quality by suppressing the apical dominance phenomenon, enhancing the C/N ratio, source capacity, and sink strength, facilitating better light and aeration inside the canopy, and maintaining lower levels of bud growth inhibitors (gibberellins and auxin) and higher levels of flower promoters (cytokinin, abscisic acid, ethylene, and proline).

Fig.-3 : Influence of branch bending on flushing, flowering, and fruiting.

❖ **What benefits does branch bending offer?**

It is easy to practice.

It is eco-friendly as it does not require costly and hazardous chemicals.

It enhances flushing, flowering, and fruiting without much removal of the biomass.

It augments uniform flowering and fruiting.

It opens up the canopy of the plant and allows better sunlight penetration and aeration in the canopy, which in turn minimizes the incidence of diseases and insects, as well as improves fruit quality.

It is a remunerative and cost-effective method of crop regulation as farmers get a better price for their off-season produce.

1. Use of abscission-inducing chemicals

Urea, ethephon, naphthalene acetic acid (NAA), potassium iodide (KI), and ortho-phosphoric acid are some chemicals that cause the abscission of leaves and fruits when employed at a certain concentration. These chemicals can be sprayed on the tree canopy in May to avoid or reduce the rainy harvest as well as to stimulate intense flushing and flowering during the summer-rainy season. However, the effectiveness of these chemicals in producing the desired results depends upon various factors, such as cultivars, climatic conditions, and the concentration of chemicals. Crop regulation studies carried out at our research station revealed the superiority of two chemicals, namely, ethephon (600-800ppm) and KI (1%) over the rest of crop regulators, i.e., urea (5-10%), NAA (500-1000ppm), and OPA (1-3%). However, considering the high cost of KI, the use of ethephon @ 600-800ppm is suggested for crop regulation in the region. Various details about ethephon and its application for the purpose of crop regulating in guava are given below :

❖ **What is ethephon?**

It is the common name of a systemic plant growth regulator (PGR) called 2-chloroethyl phosphonic acid. This versatile and multifunctional PGR controls plant growth and senescence depending upon the concentration, time of application, and plant species. Ethephon is stable in the aqueous solution below pH 4.0 but degrades and releases ethylene gas at higher pH. It is available in the market in various trade names, such as ethrel, riphon, ethegal, etc. containing 39% ethephon,

❖ **How to apply?**

The optimized dose of ethephon for crop regulation in guava is 600-800ppm. The solution can be prepared by mixing 1.5-2ml of ethephon-containing formulation, such as ethrel (39% SL), in 1 litre of water. For better spread and absorption add a surfactant (0.1%) to the spray solution. Commonly 3-5 litre spray solution is required for a well-grown tree. Spraying should be done in May during cool hours.

❖ **How does ethephon initiate abscission?**

Ethephon is easily absorbed by plants and degrades in the cytoplasmic pH to release ethylene. Elevated ethylene levels in plants reduce the polar transport of auxin into the petiole and pedicel and stimulate the synthesis of cell wall degrading enzymes, viz., cellulase and pectinase, causing detachment of leaves, flowers, and fruits.

❖ **What effects does ethephon has on the plant?**

In general, the abscission of leaves, flowers, and fruits starts on the second day of its application and completes in one week, whereas the emergence of new laterals or shoots occurs after 18–21 days of spray. Ethephon-defoliated plants produce new shoots, flowers, and fruits abundantly on account of suppression of apical dominance, activation of latent lateral buds, and stress-induced alteration of hormone levels in the plant. Fruits harvested from ethephon-treated plants have better quality in terms of total phenol, total flavonoid, and anti-oxidant properties.

2. Imposition of water stress

Under this strategy of crop regulation, a guava plant is subjected to water stress conditions immediately after harvesting of winter crop by withholding irrigation water till mid-May. By doing so undesirable flowering, i.e., *Ambe Bahar* can be reduced or avoided because, in response to water stress, the plant starts shedding its leaves and flowers and enters into a resting phase for conserving food. The basin of water-stressed trees is dug up, manured, fertilized, and irrigated during June to induce flushing and flowering (*Mrig Bahar*). In heavy soils, withholding irrigation may not be sufficient enough to impose a desirable level of stress on the plant because of the high-water holding capacity of such soil. Therefore, to exert the optimum level of water stress in heavy soil root exposure and root pruning are also practiced along with withholding of irrigation. However, root pruning and exposure may have a detrimental effect on the longevity of trees. Therefore, orchardists are suggested to be extremely careful while following these practices.

To sum up, crop regulation is one of the most critical aspects of guava cultivation, as it bears varying quantum and quality of fruits throughout the year, particularly during the rainy, winter, and spring-summer seasons. To ensure a bumper and quality harvest and keep the orchard productive for a long, it is desirable to take one crop annually. Despite low yields, the winter crop is preferred over the rainy season on account of better fruit quality and less incidence of fruit fly infestation and diseases. Harvesting peaks can be shifted to the winter season by the forceful intensification of *Mrig Bahar*. Shoot pruning, branch bending, application of abscission-inducing chemicals (defoliants), and imposition of water stress are some effective strategies for inducing profuse *Mrig Bahar* and enhancing the quantum and quality of winter harvest in guava. However, the response of guava to various methods of crop regulation varies with the agroclimatic conditions of the growing area. Since guava is cultivated under diverse agroclimatic conditions in India, *Bahar* regulation recommendation of one region can not be followed blindly in all the guava-growing regions. Therefore, location-specific standardization of the *Bahar* method and adoption of the most suitable and feasible crop regulation technique on a commercial scale are essentially required to make guava orcharding highly profitable and market-oriented.

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Chapter 7

Influence of Girdling and Root Pruningon Vegetative Growth and Physiological Factors of Fruit Trees

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Introduction

While practicing horticultural techniques viz., girdling and root pruning, it is important to take into account the planting conditions as well as the age, health and vigour of the trees. The fruit grower must keep in account the hazards involved and the anticipated advantages of following such techniques. The methodological use of such manipulation is necessary to achieve economical outcomes. Assimilates that compose the major source of energy for various stages of reproductive development, including flowering, fruit set, fruit enlargement, and fruit ripening are synthesised primarily in the canopy. The techniques girdling and root pruning are most frequently employed to promote fruit set by manipulating source- sink relationship and reducing fruitlet drop. Both practices improve physiological and biochemical components of the fruits and ultimately increase fruit production and quality. The aim of the present review is to provide a theoretical understanding and knowledge on these important practices and current issues related to them. We intend to discuss and evaluate the possible effects of girdling and root pruning on various physiological aspects of fruit trees.

Vegetative growth

The control of growth is a crucial step in the management of fruit orchards. Excessive vegetative growth leads to reduced light penetration, fruit yield, and fruit quality. Many chemical treatments were applied to control the canopy and leaf growth, but due to ecological concerns, the use of chemicals was restricted (Raja *et al.* 2018). Efforts have recently been made to use some sustainable alternatives instead of ecologically unsafe chemicals. Hence, for the management of vegetative growth and to create a balance between vegetative and reproductive growth in pear orchards, some growers tried girdling, root pruning, and summer pruning (Wang *et al.* 2014). As the vigorous vegetative growth and leaves at flowering time cause a great influence on fruit set. The trimming or pruning of young growth during the blossoming period leads to a uniform and significant increase in fruit set. Girdling may increase the abscission of mature leaves but also retard new vegetative growth. The effects showed more effectiveness for productivity when girdling was applied in the autumn, less so in the winter.

Root pruning also shows effects similar to girdling for controlling and regulating the vegetative growth of fruit trees. Root pruning can reduce resource uptake or create an imbalance in plant hormone regulation, which can negatively affect shoot growth. In addition, it is also a promising practise to overcome the alternate bearing on fruit trees, including pear, through the suppression of uncontrolled growth, promoting the maximum fruit load, and permitting better carbohydrate storage for the advancement of yield (Budiarto *et al.* 2019). Wang *et al.* (2014) observed the effect of root pruning on many fruit crops such as pear, apple, and potted grapes.

Flowering, fruit set, and fruit retention

Fruit set is low and unpredictable in some fruit crops. Many factors, such as environmental conditions, bloom date, tree health, pollination, and pollinizer

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activity, determine fruit set. Poor fruit set is observed when any of these factors are unfavourable. The number of flowers per tree indicated the fruit yield, but sometimes incomplete pollination leads to significant flower drop and less fruit set. In pear fruit, flowering occurs earlier than in apple fruit, where cool weather is more unfavourable for pollination and fertilisation. Pollination and fertilisation mainly occur at warmer temperatures and lead to fruit set. The flowers of some fruit crops are not very attractive for pollinators due to the lower amount of nectar sugar as compared to the other fruits. The fruit set can be improved in such fruit crops by using girdling, which may redistribute the stored assimilates among various sink organs. Redistribution of assimilates due to girdling may increase fruit set as it is quantitatively related to carbohydrate availability that modulates abscisic acid and ethylene levels. Less flower and fruit retention are the result of higher ethylene levels at the time of full bloom (Pasa *et al.* 2012). Girdling treatments increased flowering intensity in various fruit crops, viz., apple (Poniedziaek *et al.* 2001), peach (Sartori and Marodin 2003), and pear (Singh *et al.* 2014). Application of girdling treatments in the winter showed the maximum fruit set percentage in fruit crops. This enhancement in fruit set may be due to the availability of carbohydrates (Silva *et al.* 2010).

The other method of root pruning is the most primitive and is used to retard vegetative growth and improve flowering in many fruit trees like pear, apple, and potted grapes (Wang *et al.* 2014). The maximum number of floral bunches per tree is an indicator of improved fruit set and fruit retention and is sufficient for uniform crop development (Jana 2016). Root pruning treatment promoted flowering by encouraging root regeneration, root activity, and more cytokinin production and flowering spurs per tree (Raja *et al.* 2018).

Fruit Yield

An increase in yield is one of the major goals of horticulturists. An increase in yield is the product of fruit numbers and fruit weight. Many approaches are implemented to increase the net returns of horticultural produce. One such technique, girdling, often increases fruit yield in low-yielding trees. Shy bearing is a major problem in pear; it also exhibits high fruit drop and poor fruit growth, which leads to low yield and productivity. Therefore, many workers employed girdling to improve fruit yield and quality parameters in various fruit crops like apple, pear, peach, and olive (Nimbolkar *et al.* 2016).

Root pruning is thought to be helpful in maintaining plant vigour and health and reducing stress, which ultimately results in balanced vegetative and reproductive behaviour of the crop. It was often observed that root pruning results in a high yield per plant, which may be due to the growth of new roots resulting in new fruiting wood and a greater number of fruits per plant (Ahmad *et al.* 2006). An appropriate time for root pruning is also important to increase the yield of the crop. It was observed that late pruning induces delays in flowering time. When unfavourable weather circumstances are anticipated to shorten the fruiting season, it could result in additional time for fruit development on the tree, allowing fruits to attain their optimum growth potential. The reduction in vegetative renewal and the postponed flowering are both caused by late root cutting. The time between flowering and fruit maturity is shortened as a result (Marsal *et al.,* 2010).

Fruit size

The productivity of good and definite-sized fruits, advanced maturity, and prolonged keeping quality are the main research issues in pear fruit. Various methods have been used to enhance fruit quality, yield, and size. Among them, girdling is the best technique to manipulate the source-sink relationship and produces fruits with the best quality and size (Singh *et al.* 2014). This manipulation of the source-sink relationship leads to a reduction in crop productivity but enhances the attainability of carbohydrates and moisture to the remaining fruits, which results in an increase in fruit size. Girdling is a method that is highly used globally and is responsible for reducing vegetative growth to increase flowering and fruit size. It increases fruit size in many fruit crops, such as apple, pear, peach, and olive (Gawankar *et al.* 2019).

The adequate time of application is also advised by Sousa *et al.* (2008), who suggested that application of girdling three weeks before harvesting did not show any significant results for fruit size and quality parameters in pear cv. Rocha. They observed that the application of girdling at the optimum time reduces the competition for photosynthetic assimilation among shoot growth and fruit development. This increase in fruit size may be due to the maximum availability of assimilates towards the developing fruits because girdling creates an interruption of phloem transport and increases assimilate supply at the above-girdled area (Singh *et al.* 2014). In horticulture, girdling is used to increase fruit set and size in many crops after blocking the downward flow of metabolites by phloem, and this immediate effect of interruption is produced by leaves.

The balance between the vegetative and reproductive processes is a predominant provocation in qualitative fruit production (Sharma *et al.* 2009). There are a lot of horticultural technologies to create a proper equilibrium between vegetative growth and fruiting, such as root pruning, summer pruning, scoring, girdling, bark inversion, and plant growth regulators (Sharma *et al.* 2009). Root pruning can reduce resource uptake or create a disturbance in plant hormone regulation, which can drastically affect shoot growth. Furthermore, it is also a favourable practise to control the alternate bearing on fruit trees, including pear, by suppressing the uncontrolled growth, promoting the high fruit load, and allowing better carbohydrate storage for the advancement of yield (Budiarto *et al.* 2019). Root growth regulation is one of the promising practises to boost the yield of fruit trees, especially citrus and pear, which are economically important and high-demand fruits. Root pruning reduces fruit size due to the lower fruit expansion rate. The cell expansion rate depends on water availability and solute uptake, and any type of disturbance in water and solute uptake alters cell expansion and ultimately fruit size. Hsiao and Xu (2000) explained that the reduction in fruit size as a result of root pruning may be due to the improper availability of photoassimilates and the number of leaves during fruit growth.

Fruit weight

Fruit weight is an important quality parameter for quantifying fruit production. Different approaches are tried in order to improve the fruit weight of fruit crops and boost returns from fruit production. One such technique, girdling, has been reported to significantly increase fruit weight as well as yield in many fruit crops (Hossain *et al.* 2007). Girdling can enhance carbohydrate availability in fruits and, as a consequence, lead to an increase in fruit set and yield as well as the number of fruits (Goren *et al.,* 2003; Rivas *et al.,* 2004). The enhancement of fruit weight and leaf-to-fruit ratio is due to the maximum availability of photosynthates and less nutritional competition among developing fruits (Meitei *et al.* 2013).

Similar results were reported where fruit weight was higher in girdled trees than in the control (Poniedziaek *et al.* 2001). This was probably due to the maximum leaf-to-fruit ratio, which enhanced the flow of assimilation and improved flesh weight. The other technique is root pruning, which is also used by growers to enhance fruit set, yield, and quality. It has been advised that root pruning shows a temporary effect on carbohydrate partitioning, leading to a reduced size of the root system, which requires a smaller fraction of carbohydrates (Patterson *et al.* 2011).

Carbohydrate : Nitrogen Ratio

Because they provide energy and the building blocks for new growth before photosynthesis and the uptake of nitrogen by roots, nitrogen and carbohydrates are both crucial for the growth and development of fruit trees. Bearing trees experience both vegetative and reproductive growth. As a result, the absorbed carbon in fruit-bearing trees is divided between vegetative development and storage as well as fruit production.

In order to meet quality standards, growers have adopted a range of innovative orchard management practises. Two such practises, girdling and root pruning, are quite invasive to the plant for better fruit production and maintenance of the C:N ratio. A satisfactory balance between carbohydrates and nitrogen is important for good growth and fruit development. Girdling temporarily increases the availability of foliar carbohydrates and plant hormones for the stimulation of large numbers of flowers and the development of fruit through disruption of the source-sink ratio by temporarily removing the root system as a carbohydrate sink (Khandaker *et al.* 2011). The promotion of flowering by girdling may reflect the need for threshold levels of carbohydrate in the canopy for flower formation, besides the transport of plant hormones (Bardhan and Sharma 2018). Thus, girdling seems to remain an effective tool for growth regulation in both herbaceous and perennial plants, providing a positive effect on floral induction.

The transitory effect of root pruning on glucose partitioning results from the lesser proportion of carbohydrates needed due to the smaller size of the root system. According to Raja *et al.* (2018), it causes obstructions in the transfer of carbohydrates from leaves to roots and permits photoassimilates to build up in leaves and shoots. It is also probable that a significant portion of the carbohydrates will be lost in the roots that are removed during root trimming. Normally, spurs and shoots would use these reserves to grow. Accordingly, root pruning modifies the reserves of stored carbohydrates and affects the percentage of flowers produced (which increases when the total amount of carbohydrates in the shoot is large) (Bardhan and Sharma 2018). It was shown that in these trees, root trimming was linked to increases in bloom initiation and decreases in yield.

Percentage Return Bloom

Alternate bearer cultivars cause serious economic concern to fruit growers; therefore, growers prefer regular bearer cultivars for consistent yields and returns. Proper cultivation practises such as girdling, root pruning, and summer pruning are required through which heavy crop loads affecting return bloom can be managed.

According to Miller and Tworkoski (2003), excessive shoot growth has a negative impact on fruit quality, productivity, and pest control. The quality of the return bloom and flower bud induction are negatively impacted by shading brought on by excessive shoot growth (Miller and Tworkoski 2010). Pruning is a key strategy for regulating shoot growth. Fruit orchards also employ the practise of girdling to regulate branch growth, boost fruit set and enhance fruit quality (Ingels 2001). According to Miller and Tworkoski (2010), girdling has an impact on the partitioning of absorption and the movement of nutrients and hormones throughout the tree. High fruit set results from improved return bloom, whereas decreased return bloom results in lower yield and the emergence of alternate bearing habits.

Through the distribution of resources including carbohydrates, water, and growth regulators, training and pruning change the equilibrium between vegetative development and fruiting (Myers 2003). Heavy pruning increases the root/shoot ratio and encourages vegetative growth by decreasing leaf area, photosynthesis, and the transfer of photosynthates to fruits and roots. Root trimming slows down vegetative development, which results in the production of flowers. Metabolite build-up in nodes causes early flower bud creation. Root pruning increases flower formation due to the stimulation of various factors such as root regeneration, root activity, hormone production (cytokinin), and flowering spurs per tree (Raja *et al.* 2018). The number of flower clusters per tree is an important indicator of fruit number and yield at harvest. A uniform number of flower clusters per tree was sufficient for uniform crop development. The growth and return bloom will be larger if the crop load is low because excessive crop load causes competition for available photoassimilates.

Conclusions

Techniques such as girdling and root pruning have many horticultural implications. In physiological studies of translocation and source-sink relationship, girdling has been and continues to be a key tool as it supports the shift from agrochemical-based production towards environment friendly green farming that produces fruit without hazardous chemical residue. It offers a technique to the farmers who are constantly looking for means to cut expenses while retaining higher fruit quality. It is crucial to follow this practice judiciously in order to enhance floral production, fruit set, yield and fruit quality without posing much chemical risks. Its potential should be taken into account for its proper practice. The root trimming also offers effective growth control and helps to generate higher yield because it significantly increases return bloom. Various physiological processes viz., water stress and assimilation partitioning that maintains root-shoot equilibrium contribute to the regulation of tree growth and development. The functional efficiency of the functional roots is improved by root trimming of the structural roots. In addition to vigour control, root pruning may also be crucial for controlling vegetative response, flower induction, fruit set and fruit production. In order to control canopy size and regular bearing, it also supports the widespread adoption of root pruning in perennial fruit crops planted in high-density planting schemes.

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Chapter 8

Effects of Pathogens on Physiological Functions of Plant

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Abstract

Plant physiology is the study of plant function behavior, encompassing all the dynamic processes of growth,metabolism,reproduction, defense and communication that account for plants being alive.Plant disease is an outcome of interaction between host and pathogen. Interaction begins with physical contact and effects remain localized until host tissues have been penetrated. Depending on pathogen and the tissue they infect it interfere with the different physiological functions of the plant. Harmful effects of infection on physiology of the host are the main cause of symptoms expression, damage and loss. Human and animal survival depend on plant growth. Phytopathogen infection leads to change in secondary metabolism those induce defense programs in primary metabolism which affect growth and development of the plant,which directly or indirectly effects our economy.

Keywords : *Plant Physiology, Pathogens, Photosynthesis, Transpiration*

Introduction

Pathogens obtain their food from plants. Interfere with different physiological functions of plant and produce various symptoms.Infect flowers, roots, leaves, stem, fruits, vascular system *etc.* and decrease the growth and yield. Pathogens also hinder the translocation of water and nutrients.They are forming a huge problem on the economic and life stability. The plant pathogens are increasing in the wide world and comprise viruses, bacteria, fungi, nematode, and parasitic plant. Itcauses the diseases for leaf, stem, root, vascular system and fruit and attacks the plant by using some mechanisms that are responsible for increasing the disease and appearance the symptoms The success in the interaction between plant and plant pathogens is causing a full infection that called a compatible interaction. While another case a plant pathogen can attack the plants and growth inside the plant without causing the infection that called incompatibility interaction behavior the endophyte microbe system. Therefore, many genera of different plant pathogens invade the surface plant but not all these plant pathogens can cause the plant disease**.(Ani, 2020).**

What are Plant Pathogens

The parasitic organism that causes a disease is called **Pathogen.**The plant invaded by the pathogen and provide food source is referred as a **host**.

Plant diseases are broadly divided into biotic and abiotic.

Biotic (infectious) diseases includes fungi, bacteria, viruses, protozoa, mollicutes, nematodes, algae etc.

Abiotic (non-infectious) diseases are developed due to environmental factors includes temperature, wind, humidity, sunshine, rain *etc*

Plant Physiology

Plant physiology is the study of plant processes,

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i.e., how plants interact with their physical (abiotic) and living (biotic) environments.**(Taiz and Zeiger, 2010)**

It includes many processes like :

1. Photosynthesis
2. Respiration
3. Translocation of water, minerals
4. Transpiration

Effect on Photosynthesis

It is process of transformation of light energy into chemical energy.

It is fundamental source of light energy for all living cell animal or plant cells.

Interference in photosynthesis by pathogens due to development of chlorosis, lesions, necrotic area that causes reduction in growth and lesser number of fruits.Photosynthesis is reduced because the **leaf area is reduced**. Photosynthesis in the unaffected area remains normal. **Stomata remain partially closed**, chlorophyll is reduced and photosynthesis stops and the plant wilts**- (Evans*et al.,* 2013).**

Leaf spot caused by *Alternaria* spp. Yellowing and stunting of rice by *Tungru virus*.

Effect on Respiration in Diseased plant

Infected plants show increased respiration rate and slight rise in temperature.

Affected tissue use up their reserve carbohydrates faster than the healthy tissue.

Increase in respiration starts soon after inoculation and rises to a max. rate coincidentwith the sporulation of a fungal pathogen and then declines to normal or subnormal level.

In resistant plants the rate of increase in respiration is very rapid but declines soon while in susceptible plants respiration rises slowly but lasts for longer time.

Increase in plant metabolism and protoplasmic streaming.

Increased respiration has been noticed in cereal rusts, powdery mildews, blast of rice, late blight of potato and many other diseases.

Level of many enzymes associated with respiratory processes is increased in diseased plants.

Diseased plants carry out more fermentation than the healthy plants.

Blast of rice by *Pyricularia grisea*. Late blight of potato by *Phytopthora infestens*
(Millard and Scott, 1962)

Effect on Translocation of water and nutrients

Little or no water passes through the xylem vessels in damping off, stem rots, and cankers due to their physical blockage by the pathogen. The latter usually reach the xylem vessels in the area of the infection and, if the affected plants are young, they may cause their destruction and collapse. Affected xylem vessels may also be clogged as they may be filled with the mycelia, spores, bacterial cells, etc. and with substances secreted by the pathogen or by the host in response to the pathogen.

Plant takes inorganic nutrients and water from soil and to carry out the physiological functions.

Transport of water upward through xylem vessels of the stem into the vascular bundles of leaf petioles and veins then these enter into the leaf cells.

Pathogen interfere with the upward movement of water and inorganic nutrients and downward movement of the organic substances produced by plant.

By hindering upward movement of water, photosynthesis reduced or may stops, few or no nutrients available to the roots and other storage part of plant.

Plant starved and die**. (DS, 2017)**

Interfere with the upward movement of water and inorganic substances

Mainly by two means :

Affect the integrity of the roots.

Affecting xylem vessels.

I. Effect on Roots

Pathogens as damping off fungi, root rotting fungi and bacteria, most of nematodes and some viruses cause destruction of roots.

Some bacteria and nematodes causing root gall and root knots interfere with absorption of water.

Some vascular parasites inhibit root hair production and also change the permeability of root cells then reduce absorption. (Steudle, 2000)

Club rot of crucifers.

Root knot by causedby nematodes.

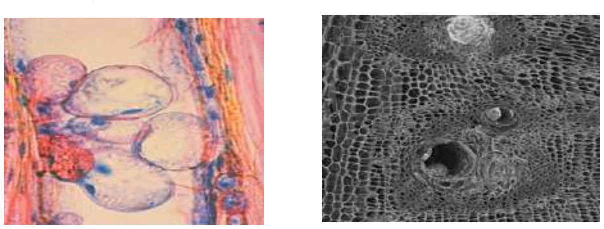
II. Affecting xylem vessels

Damping off, vascular wilts and canker causing pathogens if attack early stages **destruct and collapse** the vessels.

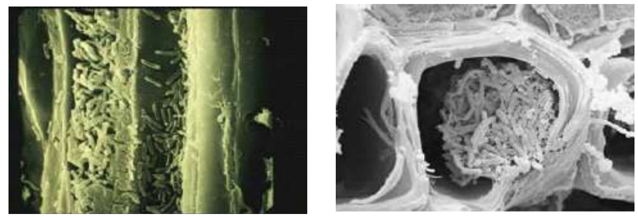
Crown gall, club rot and gall forming nematodes develope enlarged and proliferating cells near the xylem vessels exerts pressure on them then vessels **may crush and dislocate**.

The **physical presence** of pathogen in vessels as mycelium, spores or bacterial cells may block vessels.

Fusarium wilt in Gerbera- The xylem becomes clogged by mycelium and spores, and by plant produced gels, gums and tyloses. Water transport to the leaves fails, and the plant wilts **(Kwaasi, 2003).**



Tyloses and gummy polysaccharides clogging xylem vessels



Physical presence of pathogens in xylem vessels.

Effect on Transpiration

Transpiration is the process of water movement through the plant and its evaporation from aerial parts, such as leaves, stem and flowers. It is normally observed that the rate of transpiration increases in plants in which the plant diseases infect the leaves (e.g., leaf-rusts, apple scab, powdery mildews, and downy mildews). It is happens because these diseases result in destruction of at least part of the protection devices like cuticle, an increase in permeability of leaf cells, and the dysfunction of stomata.

Effects of pathogens on transpiration

Disintegeration of cuticle.

Collapse of vessels or formation of tyloses.

Powdery mildew- epidermal cells invaded by the fungus.

Rust-leaf surface get exposed due to rupture of epidermis cause unrestricted loss of water.

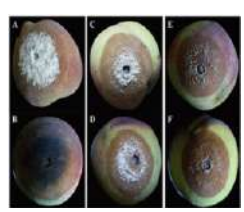
Blight-Number of active and healthy cells reduced, transport of water to leaves by xylem is reduced.

Effect of Plant Reproduction

Pathogens those affect various organs and tissues of plants **weaken and may kill**, as a results the plants remain **smaller in size**, **few fruits** and seeds, low vigor and vitality.

Pathogens can also attack flowers, fruits or seed directly.

As in brown rot of stone fruits caused by *Monilinia* sp., Bacterial canker of the stone fruits by *Pseudomonas syringae.*



Infection of *Monilinia* sp.

Fire blight by *Erwinia amylovora*

Fire blight of apple and pear caused by *Erwinia amylovora*.

Some causes **fruit drop** prematurely as in *Colletotrichum acuratum.*

In some diseases killing of the embryo**, replacing the seed contents** with fruiting structures or spores as in ergot of grains caused by *Claviceps purpurea.* In smuts of cereals and millets.

In some diseases caused by viruses, phytoplasma or phloem limited bacteria no flowers produced or sterile and less number of fruits and seeds.

Case Study

The Effects of Beet Yellow virus on the growth and Physiology of Sugar Beet (*Beta vulgaris)*

Total plant weight decrease by 20% and the root growth decreased by 25%.

It mainly decreases the lateral root development , not much affect above ground parts.

Also decrease photosynthesis, sugar content in roots and increase impurities in storage root like amino-nitrogen ,sodium and pottassium.

—(Clover*et al.,* 1999)

The Effects of Beet Yellow virus on the growth and Physiology of Sugar Beet (*Beta vulgaris*).

Future Prospects

Plant physiology is now considered as an essential ingredient for improving crop productivity,a continuing necessity with today's ever increasing world population.

Future advances in cellular and molecular biology hold promise to modify physiological processes,thereby improving the quality and quantity of major food crops and ensuring stability in yield of the produce even under severe abiotic stress.

Conclusion

Human and animal survival depend on plant growth.

Agriculture, the world's biggest bussiness, is based on ability of plants to grow and convert simple raw material to complex substances in order to suit human needs.

Even small and localised changes may have drastic consequences to the plant as a whole.

Pathogen effects plants by inducing changes in its physiological functions that leads to different types of symptoms and diseases.

This leads to the reduction in quality and quantity of plant products.

So, it directly or indirectly effects our crop economy.

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Chapter 9

Scope of "Omics" Tools in Animal Health, Nutrition and Husbandry Activities

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The word "Omics" is originated from "ome" a Greek word means all, whole or complete. This suffix is used in biosciences to describe high throughput information to understand about the life summed up in 'omes" (Yadav, 2007). Several omics studies have been taken out to analyse high throughput data of the proteins (Proteomics), genes (Genomics), mRNAs (Transcriptomics), metabolic study (Metabolomics), lipids (Lipidomics), epigenetic control expression (Epigenomics) etc in a tissue, organ at that point of time. All omics technologies are holistic as they give insight of the full set of the genes in an individual or in entire microbiome, the full set of genes get transcribed to mRNA or translated into proteins or metabolites present at a given time in a fluid, cell, organ, organisms, or population (Aardema and MacGregor, 2003). They even identify the differences in responses to temporal, ecological and behavioural changes (Odom *et al*.,2021). As these technologies can be performed with minimal invasive procedures, they are useful as diagnostics tools.

Genomics

The full set of genetic structure of an organism is called genome and study related to it is called as genomics (Chakraborty *et al.,* 2022). The term genomics was given in the year 1986 while group of scientists naming one journal. (Kuska, 1998). The major findings in this science are the discovery of genetic code, genes, Polymerase Chain Reaction, Genome sequencing either by conventional methods like Sanger sequencing or by using next Generation sequencing. In the year 2009 first time bovine genome data was published by Elsik *et al.,* 2009. The genomics era opened after the discovery of Polymerase Chain Reaction in 1985. Genome editing by using Zinc Finger Nucleases and Transcription activator like effector nucleases had opened pathways to the genomic study (Chakraborty *et al.,* 2022). Thus, omics tools helped to study genetic structure in cattle. Genome wide association studies have helped to identify regions specific for few interesting traits in livestock. Large group of genes can be mapped simultaneously to eliminate the lacunae of earlier genetic association approaches which further enhance the knowledge of few diseases. Molecular databases of NCBI (United States), EMBL (Europe), and DDBJ (Japan) provide vast information on nucleotide and protein sequences.

Transcriptomics

The complete set of RNAs produced from genome at that point of time is called transcriptome (Singh, R, 2022). Modern High throughput technologies replaced the earlier Maxam and Gilbert chemical degradation techniques. Next Generation Sequencing has helped in the quantification of omics like genomics, transcriptomics and epigenomics. In the RNA sequencing technology, messenger RNAs are fragmented at random by sheering and converted into cDNAs. These cDNAs are amplified and sequenced parallelly and mapped to a target genome (Chakraborty *et al.,* 2022). PCR free cDNA sequencing also made possible by SMRT technology. (Chakraborty *et al.,* 2022). They do not require PCR and overcome PCR biases. They produce longer reads and improve genome assembly. Sequencing with microscopy and mass spectrometry are under development. RNA sequencing has got advantages by virtue of its sensitivity, unbiased quantification of transcripts and

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full coverage of sequence expressed in a tissue. It has opened path in understanding fusion transcripts, alternate isoforms, RNA editing and splice variants etc. (Li and Wang, 2021).

Microarrays use the principle of hybridization in which sequence specific nucleotide probes are coated on chip. It is a robust technique demanding the knowledge of nucleotide sequences. However, this technique fails to distinguish two very similar sequences. Its specificity depends not only on the annealing conditions of probe and the target but also on probe length. By the method of RNA sequencing novel SNP can be captured without hybridisation challenges (Zhao et al., 2014). But it needs higher levels of computational expertise. Technological advancements reduced the cost of RNA -Sequencing recently.

Proteomics

It is the study of composition, structure, function and interactions of the proteins in the cells (Singh R., 2022). It allows analysis and quantification of proteins, their isoforms in the cell, tissue and organ in a single experiment. Wilkins and Williams described for the first time about proteomics in the middle of 1990 (Speicher, 2004).

In this technique, two-dimensional electrophoresis, chromatography, mass spectrometry etc. have opened new way to investigate animal health conditions and reproduction. (Zhao *et al.,* 2021). In MS technique, the proteins are isolated first from the biological tissues, later separated by electrophoresis, then digested by enzymic actions with the help of trypsin. These are purified by affinity chromatography or subjected for ionization by MALDI or ESI before pushing them into MS. It measures m:z ratio by various ion traps. Matching of MS spectra with database helps in identifying proteins by using various algorithms. Several modifications in MS techniques detect even post translational modifications (Chakraborty *et al.,* 2022).

Metabolomics

It is the study of the all-small molecules in an organism at a time. This is used to analyse the profiles of metabolites in the sample or sometimes quantify them. The biomarkers for the quality of milk and milk yield can be studied by analysing metabolome of different fluids of dairy animals. By this, effect of metabolism on systemic health can be checked by monitoring the compounds present in plasma and digesta. (Seidel *et al*., 2014). Carcass traits, feed conversion ratios and metabolic changes as per the environment can also be assayed. Even profiling of metabolic status of the muscle may show differences between grain and grass-fed animals by GC-MS and LC-MS. (Carrillo *et al.*, 2016) Thus, it acts as metabolic signature depicting the animal health, feeding habits and carcass quality to select animal with desired trait.

Nuclear Magnetic resonance used to analyze various biological samples and quantify different parameters in them. Peak intensities, chemical shifts and coupling patterns for qualitative and quantitative analysis of NMR metabolites act as fingerprints for that specific sample.

Metabolomics studies conducted in fat and muscles of pigs, cattle and poultry revealed differences in metabolites in tissue specific and species-specific manner. Even breeds of cattle can be distinguished by GC-MS (Ueda *et al*., 2018). Metabolomic studies conducted in Nellore cattle breed which are having higher and lower growth traits (Cansolo *et al.,* 2020). They had found that animals with higher growth had specific metabolic profile having richer concentration of distinct metabolite that affects fatty acid and protein metabolism.

Newer techniques like High resolution Mass Spectrophotometer can identify metabolites at picomolar and nanomolar concentrations and could be used to provide better view than NMR. (Goldansaz *et al.,*2017). Separation techniques like liquid, capillary and gas chromatography are combined with MS based on the nature of metabolite. Molecules are subjected to ionisation by chemical ionisation, electron ionisation and atmospheric pressure on chemical ionisation and analysed for their m/z ratio in the MS. Fourier transformation ion cyclotron resonance (FT-ICR) are used to get structural information for the identification of metabolites. Databases like Human Metabolome Database are used for matching the metabolites spectra of MS. Kyoto Encyclopaedia of Genes and Genomes (KEGG) software is used for the purpose of multivariate analysis and pathways visualisation (Fontanesi, 2016).

Faecal metabolite profiling was conducted in pigs with LC-MS by Wu *et al*., 2021 and correlated with their efficiency of feed conversion. Faecal metabolome is an indication of intestinal microbiota, digestion of the nutrients in the intestines and cellular metabolism. This metabolome is getting affected by stress conditions in beef cattle. (Valerio *et al*., 2020). So, this can act as fingerprints of tolerance status of the animals to stress as well as of feed conversion ratio.

Metagenomics

Metagenomics is the study that deals with the analysis and collection of genetic materials from all the organisms in a sample. This is mainly studied in ruminants to study microbiota in milk and rumen. Rumen microbiota gets changed as per the feed efficiency, rumen methane production and inflammatory conditions in the gut (Morgan *et al*.,2014). This provides hint to the evolutionary and phylogenetic relationships of ancestors and natives with the modern species in poultry and livestock.

Studies have been conducted in pigs, cattle and horses to analyse the mammary and gut microbiome and their connection with immunity and mastitis etc. The factors like feed intake, daily weight gain, feed conversion ratio in pigs could be affected by gut microbiota. It even helps to balance homeostasis in the animal gut by relieving immune stress. (Sun *et al*., 2021) Likewise, tapeworm infestation can alter the colonic microbiota in horses. The oral swab or faecal matter can be used for metagenomic profiling, which acts as microbial fingerprints for breeding purposes. In addition to it, studies revealed that mastitis, bacteremia and endometritis alter the milk microbiome. Thus, mammary gland health status can be assessed by the characterisation of microbiomes in the milk (Andrews *et al.,* 2019).

Glycomics

It is the study of high throughput structural analysis of glycans produced by an individual organism or components like fluid, organ and cells. The studies related glycomics are constantly increasing in recent years. New enzymatic advancements helped to liberate glycans from proteins and glycolipids.

Newer dye labelling methods and mass spectrometry has come out with wonderful outputs. Few glycans can act as biomarker representing their physiological changes in the animals. Bovine endometritis can be detected one week after the calf birth before the symptoms exhibited by the animal which usually takes one month postpartum. This marker can be screened in the maternal blood (Taran and Rudd,2016).

Bovine pregnancy associated glycoproteins are expressed in the placental trophoblast cells. The presence of these can be detected in the blood and milk of the dam from one week after insemination to till six weeks postpartum. Sandwich ELISA was used to quantify them by Krebs and co-workers successfully in 2021. This brings new hope in earlier detection of pregnancy.

Lipidomics

It is the science that deals with the various lipid species, abundances and spatial distribution. It also elaborates about their biological role in metabolic pathways and its network connections and acts as important tool to analyse them in vivo. (Han and Gross, 2003).

It is having mainly 3 steps :

1. Lipid extraction,
2. Data generation
3. Data Processing

Lipid can be extracted either in solid phase or in liquid phase based on the lipids to be extracted or the type of the sample used. Based on the solubility in solvent components target components can be separated. Liquid or Gas chromatography is used for the separation of lipids along with Mass Spectrometry. Data can be processed by univariate or multivariate analysis. Different lipid biomarkers can be traced out by these techniques. Later bioinformatic tools help to build up lipid metabolic pathways and networks (Song *et al.,*2022).

Lipid profiling in milk helps in checking the quality and characterisation of the dairy products. The variation of lipids and their contents in milk will bring variations in the nutritional values of the dairy products. The ruminant milk showed higher level saturated fatty acid levels than milk of non-ruminants, whereas 18:2n-6 and 18:3n-3 polyunsaturated fatty acids were significantly lower in ruminants than non-ruminants. (Gantner *et al.,*2015). Similarly, this study can be extended to study the differences of lipid profiles of eggs of ducks and chicken. Dietary alterations, breed and storage conditions also affect the lipid profile. Thus, lipidomics helps in the evaluation of meat, milk and egg quality to control and monitor adulteration and geographical tracing. (Song *et al.,* 2022).

Sample preparation and pooling for "omics" study

Sample must be prepared in omics experiments in careful and consistent manner. However, many of these "omics" techniques are followed as per the commercial kit. So, sample preparation is followed as per the manual guidelines in consistent manner. But this will be varied in proteomics. The methods used for isolation of proteins may vary showing different outcomes. The dynamic range is different in proteins compared to mRNA concentrations. The abundance of protein is considered to span seven orders magnitude. But while mRNAs span four orders of magnitude. (Schwanhausser et al., 2011). So, avoid confusions, many proteomes' experiments prefer multiple runs for a sample. One must choose separation method based on the purpose of the project one who is going to perform.

If single sample is not producing sufficient yield, then by pooling quantity can be increased. Pooling could reduce biological variations by an outlier and depletes the noise in the experimental data set. (Schisterman and Vexler, 2008; Bruning et al., 2015). Others have inferenced that pooling removes natural variation by generating an artificial sort of in-between phenotypes. (Bruning et al., 2015).

Analysis of data

These technologies produce huge data in gigabyte or terabyte which cannot be managed by traditional data managemental tools. Skilled statisticians, bioinformaticians and scientists are in demand to interpret these data. (Chakraborty *et al.,* 2022). The tremendous data from experimental variables like gender, parity, age, nutritional status and evaluation of genes, proteins, metabolites and transcripts needs complicated statistical tool to avoid misinterpretation of the data.

Nowadays various bioinformatics software tools available in online offline mode like EMBOSS, Linux, Biconda and Biophython etc. The handling all these data is important in omics study. It must address data filtering, transformation, normalisation, quality control and scaling etc. Molecular databases of NCBI (United States), EMBL (Europe), and DDBJ (Japan) provide vast information on nucleotide and protein sequences. Several pipelines and algorithms are available to study proteomics, metagenomics and transcriptomics. (Chakraborty *et al.,* 2022).

Conclusions

The new techniques in the sequencing and peptide analysis by mass spectrophotometer will yield better omics outputs. The deficiencies in the functional data base need to be improved. With limited grants, resources for research in animal health omics data to be extrapolated to its fullest potential (Lippolis *et al.,* 2019). Integration of all the "omics" techniques will be helpful in proper genetic selection in order to improve the production in dairy business (Chakraborty *et al.,* 2022).

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Chapter 10

Drone Technology : Changing the Future of Indian Agriculture

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Introduction

Drones in agriculture are here to stay. The development of new technologies has brought relief to farmers. However, the use of drone technology in agriculture is booming. Over the last few years, the use of drones has upsurge, and they are used in almost every sector of the economy. The drone has an adequate approach to continual agricultural life. This allows farmers, agronomists and agricultural engineers to streamline their operations and gain effective insights into crops. It has already become part of large-scale farming.

Uses of Drone Technology in Agriculture

Crop Surveillance : The drones are furnished with special imaging equipment called the Normalized Difference Vegetation Index (NDVI). The NDVI pinpoint the plant's health with detailed color information. This helps farmers monitor crops as they grow, so any problems can be dealt with quickly enough to save the plant. Drones are majorly used in the process of crop surveillance. It is the supervision of crop progress from the time seeds are sown to the time of harvest.

Drone Field Monitoring : Monitoring field conditions is important for a healthy plantation. But it becomes difficult for farmers to monitor such a large area of land. The agriculture drone monitors the health of the soil and field conditions. The drone provides accurate field information, including elevation information that helps to find irregularities in the field.

Planting and Seeding : Ten drones are capable of plating four million trees a day. Automated drone seeders are mostly used in the forestry industry right now, but they have the potential for more widespread use on the horizon. With the help of drones, one can reach the areas without endangering workers

Spray Treatment : Agro-spraying in Southeast Asia and South Korea using drones is widespread. Drone sprayers save workers from having to navigate the field with backpack sprayers, which is hazardous to their health. They deliver very fine spray applications that can be targeted to specific areas to maximize efficiency and save chemical costs. In some countries, like Canada, they are not currently legal as more testing needs to be done to understand the impact of spray drift.

Security : Monitoring the area, which used to take hours of walking, can be completed in a few minutes with the help of a drone. Apart from agriculture, the drone industry is also growing rapidly. It is considered extremely useful for farm management. The drones minute the far reaches of a farm without having to get there. This saves valuable time and allows for more frequent monitoring of hard-to-reach areas.

The drone camera provides an overview of farm operations throughout the day to ensure that the operations are running smoothly. They are also used to locate equipment, locating missing or injured animals in far-off gazing areas.

Drone AI : Artificial Intelligence and machine learning are still developing drones. It can help small farmers in developing nations. Current drone technologies are more effective in monitoring crops like corn, as they are planted in large monocultural field patterns. More work is needed to train AI systems to recognize less common crops and diverse planting patterns.

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Livestock Management : Farmers have animals such as livestock in large numbers. In this case, the livestock can be managed and monitored efficiently with the help of drones, sensors, and cameras. The drones can also identify predators before an attack and can detect sick animals.

The Benefits of Agri-Drones

As the drones are operated by trained pilots, there is no chance of their misuse.

They can increase ROI (Return on Investment).

They work at double the speed of human labor.

Drones use ULV (Ultra-low volume) spraying technology, thus it saves water and overuse of chemicals.

They are low in cost and require minimal maintenance.

They help to increase farmers' productivity.

Limitations of Agri-Drones

Connectivity issue.

Drones are dependent on weather conditions. It is advisable to not fly drones in rainy and windy weather conditions.

An average farmer may struggle to understand drone functions.

Need to obtain government clearance to use it.

Drones with more features are expensive.

How are Drones Changing the Future of Agriculture?

Drones provide an alternative source of labor on unprecedented spatiotemporal scales. The future of drones in agriculture is also promising, as drones are being developed to act as mechanical pollinators and to incorporate smart applications, making drones a promising and affordable technology to address the challenge of growing food insecurity.

The emergence of smart technology in contemporary agriculture

To address the food demands of a rising human population, agricultural practices have integrated a growing number of technologies with the aim to increase crop yield and reduce operative expenditure. This trend has led to the incorporation of so-called 'smart technologies' such as artificial intelligence and automated machinery in many stages of food production, from crop planting and livestock guarding to food processing and transport.

Drones have mostly been associated with military practices or for recreational purposes, but recent developments, particularly in sensors and imaging processing; have broadened the scope and applicability of drones. The reduction of drone costs and the increased accessibility of technologies, occurring simultaneously to technological progress, has also

One particular innovation is the use of drone technology. Drones can be described as "Unmanned Aerial Vehicles" (UAVs) but are also referred to as "Unmanned Aircraft System (UAS)," or "Unmanned Aircraft (UA)" that are piloted remotely or have been assigned a flight path by an operator.

further accelerated the popularity of drones, allowing drones to be used in other industries such as agriculture.

Modern drones now offer a range of open-source technologies, smart sensors, and longer flight times, and therefore provide a number of benefits for agricultural practices from monitoring and observation to crop protection

The diverse applications of drone technology in agriculture

A 2017 review of scientific literature by Puri et al. presented the commercial agricultural applications of drones currently applied around the world. Authors use examples from Germany, where drones are used frequently to mow meadows, determine yield losses from wild boar damage, or distribute beneficial insects among crops to act as bioremediations.

The study discusses how drones are particularly useful for improving practices of precision farming, which has gained traction in recent years. Smart, or precision farming, uses a combination of ground and satellite applications to enable site-specific processing of images to document agricultural lands. This practice provides certain autonomy without the need for invasive sampling, but also expands available spatiotemporal scales, which is compatible with drone technology.

First, drones are ideal for monitoring and sensing practices as they can rapidly cover land to monitor the growth and health of crops and soil. This is the main use of drones as their sensors are able to monitor the absorbance of a specific wavelength, forming a color contrast image visually reflecting potentially problematic areas.

This monitoring capacity not only allows for rapid processing of spatiotemporal information, but ranchers have also used drones to track livestock on ranches, as well as check for any damaged fences. To better monitor livestock, rangers have also used night cameras and thermal imagers to find any animals that are harassing and attacking herds.

The second main application for drones in agriculture is to maintain crop health through watering, fertilizer, and pesticide dispersal. Drones equipped with spectroscopy and thermography technologies can find dry areas within and address problematic areas that may have been missed by conventional watering equipment. Conversely, drones can also detect equipment leaks as well as irrigation issues.

Over time, drones can stitch thermographic images together to determine the direction of water flow across the land and identify land features that may affect water dispersion. The accuracy and rapidity of drones also allow fertilizer to be deployed to specific areas if crops are not growing sufficiently, and for pests and pathogens to be eradicated by spraying pesticides from drones themselves.

Drones can also act as mechanical pollinators, providing a third key benefit. Although insect vectors remain the most important pollinators, drones may eventually provide vital support, particularly with the decline of bees. Progress is required in this particular field, but researchers are confident drones may be able to effectively transport and disperse pollen seeds in orchards or fields.

Another key for drone application is the use of drones for agricultural investigations. From pathogens to insurance claims, drones are able to cover large areas damaged by natural disasters to uncover the causes and consequences of incidents. Agricultural insurance surveys are already applying drones to validate claims, and the fast response combined with high-resolution imaging provides the possibility to collect information over large scales, which is difficult, if not impossible, to accomplish on the same timescale if manual labor is required.

Together, these benefits make drones promising candidates for improving agricultural practices at a relatively small cost. Alongside economic benefits, optimizing fertilizer, pesticide, and water usage, to key

areas, also alleviates several ecological and environmental impacts that would not be possible conventionally.

Examples of drone types that are able to carry out all these tasks have been developed in recent years and costs for these models are decreasing consistently. For instance, in 2012, the company DJI was the first to deploy drone technology to agriculture, and offer drone technology to over 30 countries around the world and 10 million agricultural practitioners.

DJI models have recently developed the T20 plant protection drone, which can carry out control operations on many crop types. The company has also developed the sow system 2.0, which allows for drones to carry out sowing operations across entire fields or specific areas through the design of custom-made maps. Drones and their associated technologies are therefore becoming increasingly refined, and are gradually incorporating a broader range of applications.

Limitations and implications: the future of drone technology in agriculture

Despite the recognized benefits of drone technology, several challenges remain before the widespread adoption of drones across agricultural systems.

Similar to other emerging innovations, public perception of drones remains divided. This may be associated with the lack of a framework that standardizes practices of drones, thus making drones appear as a technology that is not adequately regulated and is yet to be harnessed.

A 2020 study by Ayamga et al. offers more insights into the international regulations of drones, and proposes a new approach to improving the inclusion of stakeholders and regulators to implement and enforce developed regulations, ultimately improving public perception.

Despite divided perceptions, a study by Ren et al. (2020) suggests that drones may be creating a new agricultural revolution, reaching a market value worth billions of dollars over coming years. The authors of the study suggest this may be a result of the rapidly changing environmental and demographic conditions the world is currently experiencing.

For instance, global climate change and growing food insecurity are challenges that drones can directly contribute towards by improving crop health and yield. Gerard Sylverster, editor of the UN Food and Agriculture Organization and the International Telecommunication Union's research report on "UAVs and agriculture", states that farmers work to adapt to climate change and meet other challenges, but drones are expected to help the entire agricultural enterprises improve efficiency.

In an era of rapid technological innovation, drones are also expected to improve in accuracy, duration, and applicability. The integration of software offers particularly promising results that will also improve the usability and costs, making technology more accessible to stakeholders.

This was the objective of drone developing company Drone AG, which has integrated a number of software applications. Their models now cover a crop scouting system, compatible with mobile users, as well as crop spraying drones and multispectral mapping drones.

Such innovation will bolster the efficacy of drones as well as provide farmers with more tools to maintain food security amid a rapidly changing world.

How drones can help revolutionise agriculture in India

Drones have been widely used in agriculture, including for spraying fertilisers in large farms and mapping agriculture plots. Countries like Israel even use them to pluck apples from farms. Two different drones fly from two sides, one with a cart and the other to identify apples and pluck them from the tree and put them in the basket. Such tasks can be tedious, time-consuming and expensive if done manually. Fruit plucking drones need artificial intelligence (AI) to identify the condition of the fruit and pick only the ripe ones.

Drones are being used for administering pesticides, dealing with specific pests, monitoring fields, and detecting crop disease at an early stage. The development of high-resolution, low-distortion multi-spectral camera solutions for agricultural applications allows synchronisation of multi-camera imagery from fast-flying drones with a single camera, thus enabling advanced modelling.

Data-driven solutions based on machine learning (ML), and using AI are available for analysing tree health.

In India, drones are being used to access crop damage, spray pesticides and fertilisers and tackle locust onslaughts. Depending on the purpose, a drone can be mounted with either a spraying mechanism along with a container or sensors for mapping crops. Based on the size and configuration of the drone, an agricultural drone can cost anything between Rs 1 lakh to Rs 10 lakh. The Indian government is now providing subsidies to various agricultural organisations and up to 90 per cent loans on the subsidised amount for farmers looking to procure them.

Experts feel that in India drones can be a bridge for the less affluent farmers to replicate large farmers, especially in the developed countries, who use aircraft for a variety of tasks. “For the average Indian farmer, a drone will convert the dream of being able to use an aircraft for farming into an affordable service,” said Girish Linganna, aerospace and defence expert and managing director, ADD Engineering India. Experts believe that AI is a strong suit for the Indian drone ecosystem and we must leverage our expertise in designing sophisticated systems that use drones to either minimise dependence on labour or fast-track the process.

“One AI application is seed pod planting, where AI can guide a drone to automatically shoot pods containing seeds and plant nutrients into a prepared soil patch. With more sophisticated AI, drones can detect using thermal, multi-spectral or hyper-spectral sensors where there are moisture deficits and only irrigate those areas with precision. If one adds a LiDAR (Light Detection and Ranging), sensor to the drone, with AI, a farmer will be able to estimate timber or sugarcane production. Some researchers are even working on AI-enabled software to perform faster soil analysis. This technology will create accurate 3D maps that can be used for planting planning, irrigation, estimating nitrogen levels and hence, even help the farmers plan adequate fertiliser inputs for optimal growth of crops,” said Linganna.

With the research being undertaken, an Indian farmer of the future can be envisioned using tablets while swarms of drones will buzz about. The future Indian farmer will be able to have plenty of insights that will aid them in deciding which crop to grow, its quantity, the number of fertilisers and pesticides, and much more. AI can change the face of agriculture in India.

Though experts believe that one of the most popular use cases for drones in agriculture has been spraying various chemicals like fertilisers and pesticides, as per Ramesh Kestur, a specialist in AI and agricultural drones, this use case is replete with issues. “The key problem is the downwash of chemicals. Drone-aided dispensation of chemicals is heavily influenced by flight height. Downwash is the action of changing the direction of air diverted by the drone aerodynamics during the process of lifting,” said Kestur.

The current state of India’s farmers and commercial drone solutions pose particular challenges to fully utilising drones in agriculture. According to a published report by the Indian Council of Agricultural Research’s (ICAR) National Institute of Abiotic Stress Management, India faces challenges due to weather dependency on drones, lack of proper internet connectivity across our arable farms, lack of knowledge and skill of the end users, and the potential for misuse. The report published in 2020 also spoke on the issues posed by the national laws regarding using drones for specific uses.

Benefits of drones in the agriculture sector

Drones can be used for a wide range of tasks in the agriculture sector, including crop mapping, soil analysis, irrigation, and pest management. Here are some of the key benefits of using drones in agriculture:

1. Improved efficiency : Drones can cover large areas of land quickly and efficiently, allowing farmers to gather data and monitor crops more effectively. This can help to identify issues early, leading to faster and more effective interventions.

2. Enhanced crop yields : Drones can be used to gather data on crop health, allowing farmers to identify areas that require attention. By addressing these issues, farmers can improve their crop yields and increase their profits.

3. Reduced costs : Drones can help to reduce costs by identifying areas of the farm that require attention, reducing the need for manual labour and reducing the use of pesticides and other chemicals.

4. Improved accuracy : Drones can capture high-resolution images and data, providing farmers with a detailed view of their crops. This can help to identify areas that require attention and ensure that interventions are targeted and effective.

Challenges of adopting drone technology in the agriculture sector

While drones offer many benefits to farmers, there are also some challenges that may be holding farmers back from adopting this technology. Here are some of the key challenges:

1. Fear of job loss : Many farmers are concerned that the adoption of drone technology will lead to job loss, as fewer workers will be needed to perform manual labour on the farm.

2. Lack of knowledge and training : Farmers may not have the knowledge or training necessary to operate drones effectively. This can make it difficult for them to adopt this technology, as they may not be confident in their ability to use it.

3. Cost : Drones can be expensive, and many farmers may not have the financial resources to invest in this technology.

4. Regulatory barriers : There may be regulatory barriers to the use of drones in agriculture, which could make it difficult for farmers to adopt this technology.

Is rural India afraid of losing jobs with the sole usage of drones or lack of training and proper knowledge holding the farmers back?

The adoption of drone technology in the agriculture sector in rural India is still in its early stages. While there is interest in this technology, there are also concerns about job loss and a lack of knowledge and training. However, there are efforts underway to address these challenges and encourage the adoption of drone technology.

One of the key initiatives is the Digital India campaign, which aims to provide digital infrastructure and connectivity to rural areas. This initiative includes a focus on training and education, which could help to address the lack of knowledge and training among farmers.

In addition, there are a number of organizations and initiatives that are focused on promoting the use of drone technology in agriculture. For example, the Indian Council of Agricultural Research (ICAR) has established a Centre for Precision and Farming Technologies, which is focused on promoting precision agriculture technologies, including drones.

Conclusions

Drones offer a range of benefits to farmers in the agriculture sector, including increased efficiency, improved yields, and reduced costs. However, there are also concerns about job loss and a lack of knowledge and training that may be holding farmers back from adopting this technology.

While the adoption of drone technology in rural India is still in its early stages, there are efforts underway to address these challenges and promote the use of drones in agriculture. It is important for farmers to understand the potential benefits of this technology and to receive the necessary training and support to use it effectively.

Conclusions

In conclusion, the adoption of drone technology in the agriculture sector has the potential to transform the way that farmers manage their crops and improve their yields. While there are challenges to overcome, such as concerns about job loss and a lack of knowledge and training, there are also initiatives underway to promote the use of this technology and provide support to farmers who wish to adopt it.

It is essential that farmers and policymakers work together to ensure that the benefits of drone technology in agriculture are realized, while also addressing any concerns or challenges that may arise. By doing so, we can help to create a more sustainable and productive agriculture sector that benefits both farmers and consumers alike.

Drones have the potential to revolutionize the agriculture sector. Modern technology is making things easy and more effective for future generations.

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Chapter 11

Water Footprint for Sustainable Production

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Abstract

India with more than one billion people currently has the world's second largest population. The estimate of the amount of people living in India in the year 2050 is 1.6 billion. As human populations grow, it imposes more and more demand for natural resources and the impacts are our ecological footprint. Footprints of crop production are key indicators in determining sustainability of agricultural system. Water is an important natural resource required for crop production, hence agricultural practices have a major impact on global water cycle. Water footprint (WF) is a determinant of agricultural sustainability. The concept of water footprint was first introduced by Hoekstra in 2002 and subsequently elaborated by Hoekstra and Chapagain in 2008. Water footprint refers to the total volume of direct and indirect freshwater used, consumed and polluted during all processes involved in formation of a product. The water footprint of a product is expressed in volume of water per unit of product (m^3 t^{-1}). Water is essential for agriculture and food production accounting for about 85 % of global freshwater consumption. It is found that 78 % of the global agricultural water footprint is green, 12 % is blue and 10 % is grey water footprint. WF assessment accounts for not only water consumed but also the sustainability of water use. WF can help to determine the optimal use of water and crop patterns by establishing water availability and the contribution of green, blue and grey water footprint. The water security indicators based on the water footprint concept are receiving more attention because they account for the return flow from the total water withdrawn from resources.

Key words : *Water footprint, agriculture, sustainability.*

Introduction

Over the past decades, our Earth has witnessed a significant shift from local environmental issues to global environmental change associated with an irreversible decline in natural capital stocks and ecosystem services on a global scale (Oosthoek and Gills, 2005). In striving to monitor the pressures humanity exerts on the environment, an integrated system where different impact categories can be measured through a set of appropriate indicators is needed (Giljum *et al*., 2011). The indicators of footprints have the potential to constitute a series of integrated systems with the purpose of providing a more complete picture of environmental complexity (Ridoutt and Pfister, 2013).

Footprint family

The concept of "footprint" originates from the

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idea of ecological footprint which was formally introduced to the scientific community in the 1990s (Wackernagel *et al*., 1999). Since then, many different footprint-style indicators have been created and became complementary to the ecological footprint during the last two decades including the energy footprint (Wackernagel and Rees, 1996), the water footprint (Hoekstra and Hung, 2002) the energy footprint (Zhao *et al*., 2005) the carbon footprint (Wiedmann and Minx, 2008), the biodiversity footprint (Yaap *et al*., 2010), the chemical footprint (Panko and Hitchcock., 2011) the phosphorus footprint (Wang *et al*., 2011), the nitrogen footprint (Leach *et al*., 2012) and so on. The ecological, energy, carbon and water footprints rank as the most important footprint indicators in the existing literature. This is partially because they are in close relation with the four worldwide concerns over threats to human society i.e., food security, energy security, climate security and water security (Mason and Zeitoun, 2013).

Water footprint

Human activities consume and pollute a lot of water. At a global scale, most of the water use occurs in agricultural production, but there are also substantial water volumes consumed and polluted in the industrial and domestic sectors (WWAP, 2009). Water consumption and pollution can be associated with specific activities, such as irrigation, bathing, washing, cleaning, cooling and processing. Total water consumption and pollution are generally regarded as the sum of a multitude of independent water demanding and polluting activities. There has been little attention paid to the fact that, in the end, total water consumption and pollution relate to what and how much community consumes and to the structure of the global economy that supplies the various consumer goods and services.

Until the recent past, there have been few thoughts in the science and practice of water management about water consumption and pollution along whole production and supply chains. As a result, there is little awareness regarding the fact that the organization and characteristics of a production and supply chain strongly influence the volumes (and temporal and spatial distribution) of water consumption and pollution that can be associated with a final consumer product. Hoekstra and Chapagain (2008) have shown that visualizing the hidden water use behind products can help in understanding the global character of fresh water and in quantifying the effects of consumption and trade on water resources use. The improved understanding can form a basis for a better management of the globe's freshwater resources.

Freshwater is increasingly becoming a global resource, driven by growing international trade in water-intensive commodities. Apart from regional markets, there are also global markets for water-intensive goods such as crop and livestock products, natural fibers and bio-energy. As a result, use of water resources has become spatially disconnected from the consumers. This can be illustrated for the case of cotton. From field to end product, cotton passes through a number of distinct production stages with different impacts on water resources. These stages of production are often located in different places and final consumption can be in yet another place. For example, Malaysia does not grow cotton, but imports raw cotton from China, India and Pakistan for processing in the textile industry and exports cotton clothes to the European market (Chapagain *et al*, 2006). As a result, the impacts of consumption of a final cotton product on the globe's water resources can only be found by looking at the supply chain and tracing the origins of the product. Uncovering the hidden link between consumption and water use can form the basis for the formulation of new strategies of water governance, because new triggers for change can be identified. Where final consumers, retailers, food industries and traders in water-intensive products have traditionally been out of the scope of those who studied or were responsible for good water governance, these players enter the picture now as potential 'change agents'. They can be addressed now not only in their role as direct water users, but also in their role as indirect water users.

Water footprint concept

The concept of 'water footprint' introduced by Hoekstra (2002) and subsequently elaborated by Hoekstra and Chapagain (2008) provides a framework to analyze the link between human consumption and the appropriation of the globe's freshwater. Water footprint defined as measure of humanity's usage of fresh water in terms of volume of water consumed or polluted, expressed in cubic meters per unit time (Hoekstra and Hung, 2002). The water footprint of a product is defined as the total volume of freshwater that is used to produce the product (Hoekstra *et al*., 2009) or it is a measure of humanity's appropriation of fresh water in volumes of water consumed and/or polluted. Water use is measured in terms of water volumes consumed (evaporated or incorporated into a product) and/or polluted per unit of time. A water footprint can be calculated for a particular product, for any well-defined group of consumers (for example, an individual, family, village, city, province, state or nation) or producers (for example, a public organization, private enterprise or economic sector).

The water footprint is a geographically explicit indicator, showing not only volumes of water use and pollution, but also the locations. (Hoekstra, 2011).

The water footprint is an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at the indirect water use. The water footprint can be regarded as a comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal. The water footprint of a product is the volume of freshwater used to produce the product, measured over the full supply chain. It is a multidimensional indicator, showing water consumption volumes by source and polluted volumes by type of pollution; all components of a total water footprint are specified geographically and temporally.

The water footprint of a process is expressed as water volume per unit of time. When divided over the quantity of product that results from the process (product units per unit of time), it can also be expressed as water volume per product unit. The water footprint of a product is always expressed as water volume per product unit.

Examples :

Water volume per unit of mass (for products where weight is a good indicator of quantity)

Water volume per unit of money (for products where value tells more than weight)

Water volume per piece (for products that are counted per piece rather than weight)

Water volume per unit of energy (per kcal for food products, or per joule for electricity or fuels)

Why water footprint is important?

Freshwater is a scarce resource; its annual availability is limited and demand is growing. The water footprint of humanity has exceeded sustainable levels at several places and is unequally distributed among people.

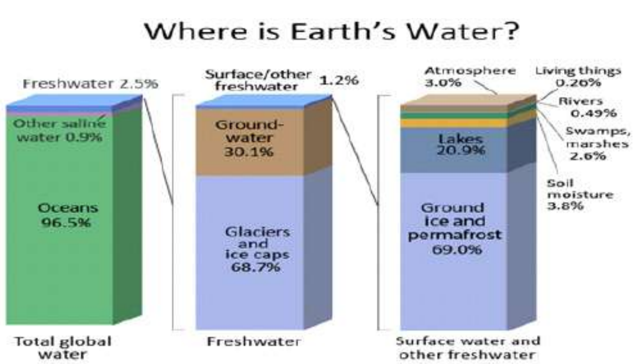
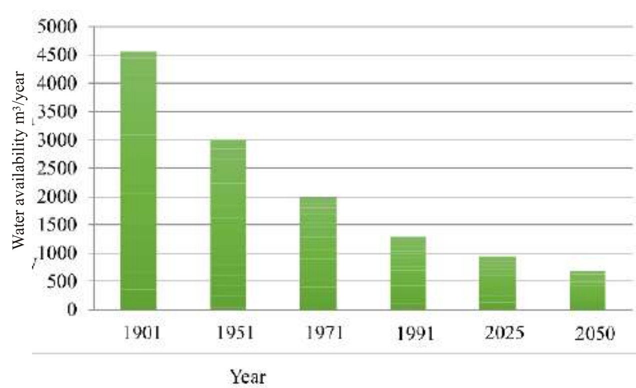


Fig.-1 : Distribution of earth's water.

In the above Figure-1, the first bar notice that only 2.5% of Earth's water is freshwater-the amount needed for life to survive. The middle bar shows the breakdown of freshwater. Almost all of it is locked up in ice and in the ground. Only a little more than 1.2% of all freshwater is surface water, which serves most of life's needs. The right bar shows the breakdown of surface freshwater. Most of this water is locked up in ice, and another 20.9% is found in lakes. Rivers make up 0.49% of surface freshwater. Although rivers account for only a small amount of freshwater, this is where humans get a large portion of their water from. (FAO, 2015).

Freshwater is vital to life, and as the world's population grows, so does our use of it. Globally, the demand of water is increase for people drinking and bathing, but as developing countries like China and India grow more prosperous, more people are consuming more water-intensive food, electricity and consumer goods.



Graph-1 : India's per capita water availability.
(Source : Vivek P. Kapadia, Government of Gujarat, 2016)

Table-1 : Water resource at a glance.

Water Resource at a Glance	Quantity Km^3	Percentage
Estimated water need in 2050	1450	129
Estimated deficit	327	29
Interlinking can give us	200	17.8

(Source : Water Resources at a Glance 2011 Report).

Components of water footprint

Green water footprint

The green water footprint is an indicator of the human use of so-called green water. Green water refers to the precipitation on land that does not run off or recharges the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (but not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth). The green water footprint is the volume of rainwater consumed during the production process. This is particularly relevant for agricultural and forestry products (products based on crops or wood), where it refers to the total rainwater evapotranspiration (from fields and plantations) plus the water incorporated into the harvested crop or wood.

The green water footprint in a process step is equal to :

$WF_{proc,\ green}$= Green Water Evaporation + Green Water Incorporation [volume/time]

The distinction between the blue and green water footprint is important because the hydrological, environmental and social impacts, as well as the economic opportunity costs of surface and groundwater use for production, differ distinctively from the impacts and costs of rainwater use (Falkenmark and Rockström, 2004; Hoekstra and Chapagain, 2008).Green water consumption in agriculture can be measured or estimated with a set of empirical formulas or with a crop model suitable for estimating evapotranspiration based on input data on climate, soil and crop characteristics.

Blue water footprint

The blue water footprint is an indicator of consumptive use of so-called blue water, in other words, fresh surface or groundwater. The term 'consumptive water use' refers to one of the following four cases are :

Water evaporation

Water is incorporated into the product

Water does not return to the same catchment area, for example, it is returned to another catchment area or the sea

Water does not return in the same period, for example, it is withdrawn in a scarce period and returned in a wet period.

The first component, evaporation, is generally the most significant one. Therefore, one will often see that consumptive use is equated with evaporation, but the other three components should be included when relevant. All production related evaporation counts, including the water that evaporates during water storage (for example, from artificial water reservoirs), transport (for example, from open canals), processing (for example, evaporation of heated water that is not recollected) and collection and disposal (for example, from drainage canals and from wastewater treatment plants).

Water is a renewable resource, but that does not mean that its availability is unlimited. In a certain period, the amount of water that recharges groundwater reserves and that flows through a river is always limited to a certain amount. Water in rivers and aquifers can be used for irrigation or industrial or domestic purposes. But in a certain period one cannot consume more water than is available. The blue water footprint measures the amount of water available in a certain period that is consumed (in other words, not immediately returned within the same catchment). In this way, it provides a measure of the amount of available blue water consumed by humans. The remainder, the groundwater and surface water flows not consumed for human purposes, is left to sustain the ecosystems that depend on the groundwater and surface water flows.

The blue water footprint in a process step is calculated as :

$WF_{proc,blue}$= Blue Water Evaporation+ Blue Water Incorporation + Lost Return flow [volume/time]

Grey water footprint

The grey water footprint is an indicator of the degree of freshwater pollution that can be associated with the process step. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards. The grey water footprint concept has grown out of the recognition that the size of water pollution can be expressed in terms of the volume of water that is required to dilute pollutants such that they become harmless.

The grey water footprint is calculated by dividing the pollutant load (L, in mas/time) by the difference between the ambient water quality standard for that pollutant (the maximum acceptable concentration C_{max}, in mass/volume) and its natural concentration in the receiving water body (C_{nat}, in mass/volume).

$$\mathbf{W_{proc,\ grey} = L/C_{max} - C_{nat}}$$

The natural concentration in a receiving water body is the concentration in the water body that would occur if there were no human disturbances in the catchment. For human-made substances that naturally do not occur in water, C_{nat} = 0. When natural concentrations are not known precisely but are estimated to be low, for simplicity one may assume C_{nat} = 0. This will, however, result in an under estimated grey water footprint when C_{nat} is actually not equal to zero.

One may ask why the natural concentration is used as a reference and not the actual concentration in the receiving water body. The reason is that the grey water footprint is an indicator of appropriated assimilation capacity.

The assimilation capacity of a receiving water body depends on the difference between the maximum allowable and the natural concentration of a substance. If one would compare the maximum allowable concentration with the actual concentration of a substance, one would look at the remaining assimilation capacity, which is obviously changing all the time, as a function of the actual level of pollution at a certain time (Hoekstra *et al*., 2011).

Water footprint of Nation

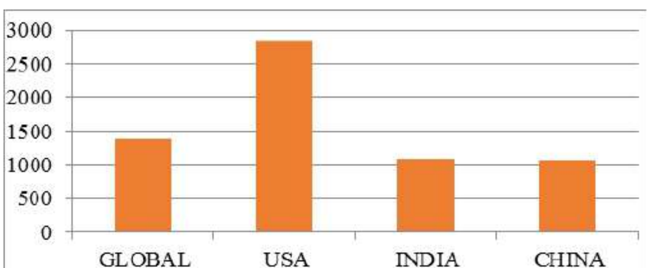
The water footprint is an indicator of water use that looks at both direct and indirect water use. The water footprint of a nation is defined as the total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation.The water footprint of a nation has two components.

The internal water footprint is defined as the water use within the country in so far it is used to produce goods and services consumed by the national population. The external water footprint of a country is defined as the annual volume of water resources used in other countries to produce goods and services imported into and consumed in the country considered. Figure-2 shows a visual representation of the national water footprint accounting scheme as was introduced by Hoekstra and Chapagain (2008).

Consumption characteristics

- ✓ Consumption pattern
- ✓ Consumption volume

USA has higher meat consumption than most of the countries ranges 120kg/capita/yr. Also it has higher industrial consumption and more usage of Water intensive products.



Graph-2. Water Footprint of India in m^3/Capita/Yr

In the above graph-2 (Hoekstra, 2014) depicted that USA having higher WF. The reason for higher WF in USA (2842 m^3/Capita/Yr.) is due to their higher consumption of water for industrial purpose. The reason for higher WF in case of China (1071m^3/Capita/Yr.) than India (1089 m^3/Capita/Yr.) is due to their efficient water usage in agriculture because of technology are using. i.e., their water productivity is high. The Global average WF is (1385 m^3/Capita/Yr.).

Water footprint of India

India has the largest total WF any country in the world (987 billion m^3 year $^{-1}$)

India has low per capita WF of 980 m^3 year $^{-1}$ Lower than that of many other countries

India contributes 17 % to the global population, Indian people contribute only 13 % to the global WF.

India's individual's daily water footprint is around 3000 litres, while in China about 2934 litres.

In India, consumption of agricultural products alone largely determines the global water footprint related to consumption, contributing 92% to the total water footprint.

Table-2. Water footprint in billion m^3/yr.

Blue water footprint	227 (29%)
Green water footprint	459 (59%)
Grey water footprint	92 (12%)
Total water footprint	778

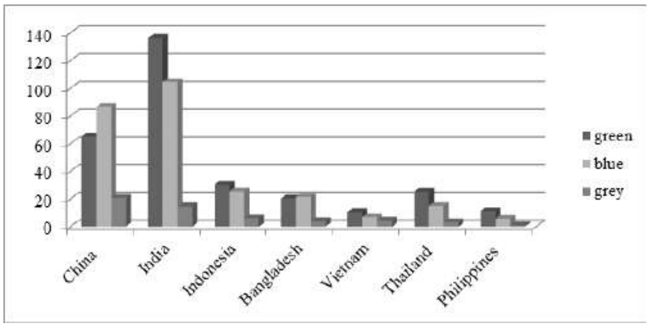
This table-2 shows that water use in relation to the consumption of agricultural goods in the Indian states.

Water footprint of major crops

Water footprint of Rice

Rice is one of the major staple crop feeding the world population and is most important ingredient in food composition in South Asia and Africa. For rice cultivation in wetland systems, paddy fields are prepared and the soil is kept saturated. The common practice is to first prepare land by puddling. This is done by saturating the soil layer for 1 month prior to sowing. The volume of water (SAT) necessary for this stage is assumed to be 200 mm as suggested by Brouwer and Heibloem (1986). As lowland rice is grown in a standing layer of water, there is a constant percolation and seepage loss during this period. Percolation loss (PERC) is primarily a function of soil texture. It varies from 2 mm/day (heavy clay) to 6 mm/day for sandy soil.

According Chapagain and Hoekstra (2011) the national water footprint of rice production and consumption is estimated using international trade and domestic production data for 13 major rice producing countries. The global water footprint of rice production is 784 km^3/year with an average of 1325 m^3/t which is 48% green, 44% blue, and 8% grey. There is also 1025 m^3/t of percolation in rice production. The ratio of green to blue water varies greatly over time and space. In India, Indonesia, Vietnam, Thailand, Myanmar and the Philippines, the green water fraction is substantially larger (from graph-3) than the blue one, whereas in the USA and Pakistan the blue water footprint is 4 times more than the green component. The virtual water flows related to international rice trade was 31 km^3/year.



Graph-3 : Blue, Green and Grey WF fractions of different countries.

Wheat

To estimate the green, blue and grey water footprint of wheat in a spatially-explicit way, both from a production and consumption perspective. The assessment is global and improves upon earlier research by taking a high-resolution approach, estimating the water footprint of the crop at a 5 by 5 arc minute grid. We have used a grid-based dynamic water balance model to calculate crop water use over time, with a time step of one day. The model takes into account the daily soil water balance and climatic conditions for each grid cell. In addition, the water pollution associated with the use of nitrogen fertilizer in wheat production is estimated for each grid cell.

The global wheat production in the period 1996-2005 required about 1088 billion cubic meters of water per year. The major portion of this water (70%) comes from green water, about 19% comes from blue water and the remaining 11% is grey water. The global average water footprint of wheat per ton of crop was 1830 m^3/ton. About 18% of the water footprint related to the production of wheat is meant not for domestic consumption but for export. About 55% of the virtual water export comes from the USA, Canada and Australia alone. For the period 1996-2005, the global average water saving from international trade in wheat products was 65 Gm3/yr.

A relatively large total blue water footprint as a result of wheat production is observed in the Ganges and Indus river basins, which are known for their water stress problems. The two basins alone account for about 47% of the blue water footprint related to global wheat production. About 93% of the water footprint of wheat consumption in Japan lies in other countries, particularly the USA, Australia and Canada. In Italy, with an average wheat consumption of 150 kg/yr per person, more than two times the word average, about 44% of the total water footprint related to this wheat consumption lies outside Italy. The major part of this external water footprint of Italy lies in France and the USA.

Water footprint of maize

Duan and Qin (2014) calculated the green, blue, grey and total WFs of maize production in Northeast China from 1998 to 2012 and compared the values of the provinces. This study also analyzed the spatial variation and structure characteristics of the WPFs. The annual average WF of maize production was 1029?m^3 ton^{-1}, which was 51% green, 21% blue and 28% grey.

Water footprint of banana

Global average - 790 L kg^{-1}

India - 500 L kg^{-1}

On average, one large banana (200 gram) costs 160 litres of water

Water footprint of product

The water footprint of a product is defined as the total volume of fresh water that is used directly or indirectly to produce the product. It is estimated by considering water consumption and pollution in all steps of the production chain. The accounting procedure is similar to all sorts of products, be it products derived from the agricultural, industrial or service sector. The water footprint of a product breaks down into a green, blue and grey component. An alternative term for the water footprint of a product is its 'virtual-water content', but the meaning of the latter term is narrower.

The water footprint of a product is similar to what in other publications has been called alternatively the 'virtual-water content' of the product or the product's embedded, embodied, exogenous or shadow water (Hoekstra and Chapagain, 2008). The terms virtual-water content and embedded water, however, refer to the water volume embodied in the product alone, while the term 'water footprint' refers not only to the volume, but also to the sort of water that was used (green, blue, and grey) and to when and where the water was used. The water footprint of a product is thus a multidimensional indicator, whereas 'virtual-water content' or 'embedded water' refer to a volume alone.

Water footprint of cotton consumption

Water foot print of cotton – 256 Gm^3 /year

Blue WF – 42 %

Green WF – 39 %

Grey WF – 19 %

The global average water footprint of cotton fabric is 10,000 liter per kilogram. That means that one cotton shirt of 250 gram costs about 2500 liter. Jeans of 800 gram will cost 8000 liter. These figures are global averages. The water footprint of cotton fabric varies from place to place. The water footprint of cotton fabric made with cotton from China is 6000 liter/kg. For cotton from the USA this is 8100 liter/kg, for cotton from India 22500 liter/kg, for cotton from Pakistan 9600 litre/kg and for cotton from Uzbekistan 9200 liter/kg (Mekonnen and Hoekstra, 2011). The proportion of blue water in the water footprint of cotton is relatively large, because cotton is often irrigated. On average, one third of the water footprint of cotton is blue water. For some countries, the blue water proportion is much larger, like for example in Uzbekistan (88%) and Pakistan (55%). The water use of cotton has often greater local impacts. In Central Asia, for example, excessive abstractions of water from the Amur Darya and Syr Darya for cotton irrigation have resulted in the near-disappearance of the Aral Sea. In the period 1996-2005, global cotton production contributed 3% to the total water footprint of crop production in the world (Mekonnen and Hoekstra, 2011).

Table-3 : Total water footprint for different products.

Product	Standard weight (g)	Blue water footprint (L)	Green water foot-print (L)	Grey water foot-print (L)	Total volume of Water (L)
1 pair of Jeans	1000	4900	4450	1500	10,850
1 Single bed sheets	900	4400	4000	1350	9750
1 T-shirt	250	1230	1110	380	2720
1 Johnson's cotton bud	0.333	1.6	1.5	0.5	3.6

Water footprint of coffee and tea

The water footprint of coffee (140 L cup^{-1}, based on use of 7 gram of roasted coffee per cup) is much larger than the water footprint of tea (27 L cup^{-1}, based on use of 3 gram of black tea per cup) (Chapagain and Hoekstra, 2007).

The green, blue and grey water footprint of farm animals and animal products

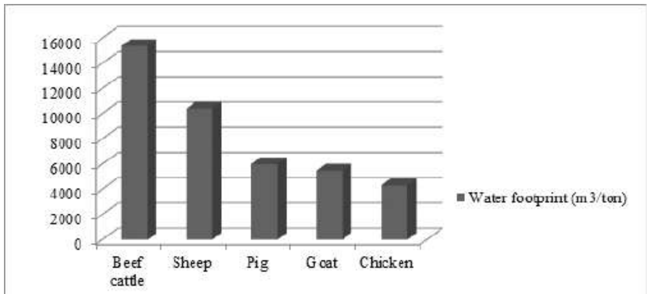
Water footprint of global animal production – 2422 Gm^3 /year

Green WF – 87 .2 %

Blue WF – 6.2 %

Grey WF – 6.6 %

In general, animal products have a larger water footprint per tonne of product than crops. From a fresh water resource perspective, it appears more efficient to obtain calories, protein and fat through crop products than animal products. Most of the water footprint comes from the animal feed and the animal drinking water only accounts for a minor share. Three key parameters affect the water footprint of animals: feed conversion efficiency of the animal, feed composition and feed origin. The nature of the production system – whether grazing, mixed or industrial – is important because it has an effect on all the three parameters.



Graph.4. Water footprint (m^3/ton)

Among the meat products the WF from above graph-4 has been estimated to be in the order of beef (15,500 l kg^{-1}) > sheep meat (10,412 L kg^{-1}) > goat meat (4521 L kg^{-1}) > chicken (3364 L kg^{-1}).

The global average water footprint of whole cow milk is about 940 liters/kg. About 28% of this amount is allocated to the butter that is derived from the whole milk and the remaining 72% to skim milk. One kilogram of whole milk gives about 50 gram of butter, so that the water footprint of butter is 5550 liter/kg.

Although beef cattle, sheep and goat require much more feed per unit of meat produced than pig and broiler chicken, the fraction of concentrate feed in the total feed is much larger for the latter. Since concentrate feed has a larger water footprint per unit of weight than roughages. The water footprints of the different sorts of meat are closer than one would expect on the basis of feed conversion efficiencies alone.

The total water footprint of an animal product is generally larger when obtained from a grazing system than when produced from an industrial system, because of a larger green water footprint component. The blue and grey water footprints of animal products are largest for industrial systems (with an exception for chicken products). From a freshwater perspective, animal products from grazing systems are therefore to be preferred above products from industrial systems. 29% of the total water footprint of the agricultural sector in the world is related to the production of animal products. One third of the global water footprint of animal production is related to beef cattle.

Water footprint responses

Ways to reduce green and blue water footprint

Reduced tillage, which promotes increased water-use efficiency.

Increase land productivity (yield, ton/ha) by improving agricultural practice; since the rain on the field remains the same, water productivity (ton/ m^3) will increase and the green water footprint (m^3/ ton) will reduce.

Rain water Harvesting.

Agricultural water management

Irrigation for crops takes about 85 to 90 per cent of fresh water in India, but only 50 per cent in developed countries. The average irrigation efficiency in canal/tank irrigation is only about 35-40 per cent. Paddy irrigation consumes about 72 per cent of water allocated for agriculture in Tamil Nadu and sugarcane irrigation takes about 70 per cent in Maharashtra state. Though research on water management has evolved many technologies to save water in surface methods like paired row method, alternated furrow irrigation, forming long furrows, reduction of basins for horticultural crops but it is not followed in large scale by farmers. For many crops, drip irrigation crops saves 45-50% compared to surface method.

The task forces on micro irrigation/drip irrigation has estimated that about 27 M ha of land for Vegetables, fruits and plantation crops, sugarcane, cotton, coconut crops can be brought under drip method and sprinkler irrigation can be used in 42.5 M ha for pulses, cereals *etc.* through only about 3 M ha are irrigated by sprinkler and drip at present.

—In India, paddy crop alone uses about 45 per cent of total irrigation water which can be reduced by adopting SRI method and at the same time, yield can be increased by 30 – 40%. Similarly, Sugarcane, banana and other orchard crops can be irrigated by drip method to save water and to increase the yield. Further, it is important to change the cropping pattern and method of irrigation to save water and bring more area under irrigation to solve the water crisis/scarcity.

How to conserve ground water

The actual movement ground water is not predictable. For all practical purposes we assume that the quantity of water that we harvest in particular watershed above ground level is stored in underground aquifer within that watershed boundary itself. The quantity of storage is also not accurately predictable. Indiscriminate pumping coupled with failure in monsoon results in none matching of 'recharge' to that of the 'drawl'. Hence, it is apparent that the total quantity of water available in the underground reservoir is decreasing day by day due to over-exploitation for Agricultural and Industrial and Domestic purpose.

In case of agricultural purpose : The only option to show improvement in this scenario is adopting proper management practices in utilization of groundwater. Adopting Drip / Sprinkler system leads to savings of conveyance loss and application loss. These losses amount to almost 30-40%. Studies show that delivery of 50% water compared to conventional method is sufficient for the crops if we adopt management information systems. The canal water cannot be directly used in drip system without installing a pumping unit and a sump.

Advanced irrigation technologies like drip and sprinkler irrigation methods are preferable to less efficient traditional surface methods to achieve higher crop and water productivity. Deficit irrigation is one way of maximizing the water use efficiency (WUE) for higher yields per unit of irrigation water applied.

Eg: Cotton crop which is having higher water footprint (256 Gm^3 /year) than most of the other field crops. So in order to reduce water footprint of cotton we can adopt deficit irrigation. Because cotton and also maize are suitable crop for deficit irrigation to achieve higher WUE.

Use of organic mulches to reduce evaporation.

Ways to reduce grey water footprint

The grey water footprint can be reduced to zero by preventing the application of chemicals to the field. It can be lowered substantially by applying less chemicals and employing better techniques and timing of application (so that less chemicals arrive in the water system by run-off from the field or by leaching). In theory, the grey water footprint can be brought back to zero through organic farming. In practice, it will be quite a challenge and require substantial time before all conventional farming can be replaced by organic farming.

Apply less or no chemicals (artificial fertilisers, pesticides), e.g. organic farming.

Apply fertilisers or compost in a form that allows easy uptake, so leaching is reduced.

Prevent Soil erosion.

Optimise the timing and technique of adding chemicals.

Adopt "3R Principle" for industrial use.

Measures to reduce water footprint of consumers

Reduction of the direct water footprint

Reduction of the indirect water footprint

Ask product transparency from businesses and regulation from governments

Conclusions

Globally per capita water availability decreasing due to population pressure. Water footprint helps to understand how much water is required to produce product and address the challenges of global water stress. Water footprint of nation depends on climatic condition and consumption pattern of peoples. Water footprint reduction in irrigated crop production is the way forward for ef?cient and sustainable water resource use. Reduction in consumptive WF of a crop at ?eld level can be achieved by changing management practice such as irrigation technique, irrigation strategy and mulching practice.

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Chapter 12

MIllets : Traditional Wonder Food

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Introduction

Millet is widely used to refer to a variety of grains that are very popular for their culinary uses as well as their health promoting qualities. In the era of 21st century, rapid urbanisation, climate change, increased population, scarcity of water and increased dry land are the factors responsible for the worldwide agricultural and nutritional challenges. Minor millets are also full of micronutrients like Mg, Ca, Mn, tryptophan, phosphorous, fibre, B vitamins. These micronutrients act as antioxidants which are essential to human body. Millet is one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes. Several bioactive principles in Millets are known to decrease cardiovascular risk,diabetes, ageing and even cancer. However, nutritive and therapeutic potentials of bioactive compounds found in Millets are underexplored and a systematic review encompassing available data in literature is grossly missing. Millet is delicious as a cooked cereal that can be used as a side dish and can be popped like corn for use as a snack or breakfast cereal. Properly stored, whole millet can be kept safe for up to two years.Millet is a highly nutritious, healthy and versatile grain that would be worthy adding to anyone's diet.

Millets have long been the staple food in the country. But polished rice, processed sugar and other refined food products produced using chemical fertilizers have become part of our daily life now. With no alternative, people have got accustomed to it and getting in the process, among other health disorders, diabetes, blood pressure and obesity. In addition to vitamins, Millets are the rich source of flavanoids such as apigenin, catechin, daisein, orientin, isoorientin, lutolin, quercetin, vitexin, isovitexin, myricetin sponarin, violanthin, lucenin-1, and tricin. Further, the presence of essential amino acids enriches the nutritive potential of Millets. Several bioactive principles in Millets are known to decrease cardiovascular risk, diabetes, ageing and even cancer. However, nutritive and therapeutic potentials of bioactive compounds found in Millets are underexplored and a systematic review encompassing available data in literature is grossly missing. Fig. 1 shows General structure of millet grain.

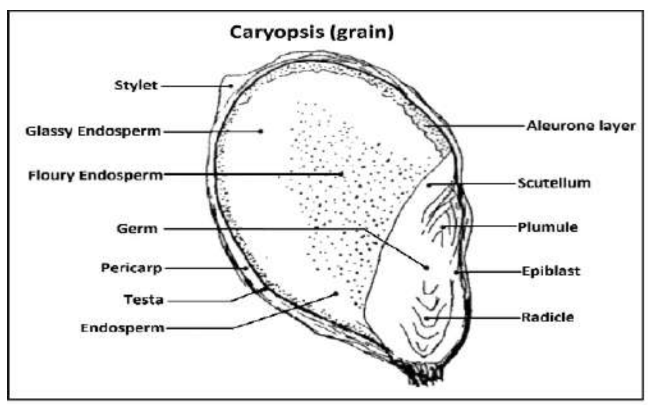

Fig.-1 : General structure of millet grain.
Reference : Nutritional and Health Benefits of Millets, ICAR–Indian Institute of Millets Research (IIMR) Hyderabad (2017).

Nutritional Composition of Millets and its health benefits

Madhya Pradesh has highest area of small millets (32.4%) followed by Chhattisgarh (19.5%), Uttarakhand (8%), Maharashtra (7.8%), Gujarat

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Table-1 : Vernacular Names of Millet.

English	Sorghum	Pearl Millet	Finger millet	Little millet	Kodo millet	Foxtail/ Italian millet	Barnyard millet	Proso millet
Hindi	Jowar	Bajra	Mandua	Kutki	Kodon	Kangni, Kakum	Sanwa, Jhangon	Barre
Sanskrit	-	-	Nandimukhi, Madhuli	-	Kodara	Kanguni	Shyama	Chiná
Kannada	Jola	Sajjai	Ragi	Same	Harka	Navane	Oodalu	Baragu
Tamil	Cholam	Kamboo	Kelvaragu	Samai	Varagu	Tenai	Kuthiravaali	Panivaragu
Telugu	Jonna	Sajjalu	Ragulu	Samalu	Arikelu, Arika	Korra, Korralu	Udalu, Kodisama	Varigulu, Varagalu
Malayalam	Cholam	Kamboo	Moothari	Chama	Varagu	Thina	-	Panivaragu
Marathi	Jcwari	Bajri	Nachni	Sava	Kodra	Kang, Rala	Shamul	Vari
Gujarati	Juar	Bajri	Nagli, Bavto	Gajro, Kuri	Kodra	Kang	Sama	Cheno
Bengali	Juar	Bajra	Mandua	Kangani	Kodo	Kaon	Shamula	Cheena
Punjabi	-	Bajra	Mandhuka, Mandhal	Swank	Kodra	Kangni	Swank	Cheena

Reference : Nutritional and Health Benefits of Millets, ICAR–INDIAN INSTITUTE OF MILLETS RESEARCH (IIMR) Hyderabad (2017).

Table-2 : Nutrient composition of millets compared to fine cereals (per 100 g).

Food gain	Carbo-hydrates (g)	Protein (g)	Fat (g)	Energy (K.Cal)	Crude fibre (g)	Mineral matter (g)	Ca (mg)	P (mg)	Fe (mg)
Minor millets									
Finger millet	72.0	7.3	1.3	328	3.6	2.7	344	283	3.9
Kodo millet	65.9	8.3	1.4	309	9.0	2.6	27	188	0.5
Proso millet	70.4	12.5	1.1	341	2.2	1.9	14	206	0.8
Foxtail millet	60.9	12.3	4.3	331	8.0	3.3	31	290	2.8
Little millet	67.0	7.7	4.7	341	7.6	1.5	17	220	9.3
Barnyard millet	65.5	6.2	2.2	307	9.8	4.4	20	280	5.0
Millet									
Sorghum	72.6	10.4	1.9	349	1.6	1.6	25	222	4.1
Bajra	67.5	11.6	5.0	361	1.2	2.3	42	296	8.0
Cereals									
Wheat (whole)	71.2	11.8	1.5	346	1.2	1.5	41	306	5.3
Rice (raw, milled)	78.2	6.8	0.5	345	0.2	0.6	10	160	0.7

(Source : Nutritive value of Indian foods, NIN, 2007).

(5.3%) and Tamil Nadu (3.9%). Uttrakhand has highest productivity of 1174 Kg/ha followed by Tamil Nadu (1067 Kg/ha) and Gujarat (1056 Kg/ha).

Cardiovascular diseases, cancer, celiac disease etc are most prominent because of inadequate supply of nutrition. This is mainly due to the lack of awareness and knowledge among the people in choosing the kind of food, especially the small millets. Millets are easily available and cheap in cost. Millets contains many major and minor nutrients like carbohydrates, protein, fat, dietary fiber, vitamins and minerals as well as antioxidants and phytochemicals. The importance of this study undertakes to concern and to develop specific agenda for these crops which must be recognized as an important food and to introduce the millets as a nutritious food for fulfillment of the nutritional need of the global population and reduce the problems of malnutrition and other health. Table -1 indicates Vernacular Names of Millets.

Millet and other whole grains are a rich source of magnesium, a mineral that acts as a co-factor for more than 300 enzymes, including enzymes involved in the body's use of glucose and insulin secretion. Studied showed that type 2 diabetes was 31% lower in women who frequently ate whole grains compared to those eating the least of these magnesium-rich foods. When the women's take high magnesium in their diet ,it shows a beneficial, but lesser 19% reduction in risk of type 2 diabetes and promoting healthy blood sugar control8.

Kodo millet contains protein (8.3%) and crude fiber (9%) when compared with others. It has least phosphorus content of all the millets and the mineral matter is 2.6gm/100gm grain according to Hegde and

Table-3 : Vitamins of millets compared to fine cereals (per 100 g).

Millet/mi or millets	Thiamin (mg)	Niacinn (mg)	Riboflavin	Vit A	Vit B6 (mg/100g)	Folic Acid (mg/100g)	Vit B5 (mg/100g)	Vit E (mg/100g)
Foxtail	0.59	3.2	0.11	32	-	15.0	0.82	31.0
Proso	0.41	4.5	0.28	0	-	-	1.2	-
Finger	0.42	1.1	0.19	42	-	18.3	-	22.0
Little	0.3	3.2	0.09	0	-	9.0	-	-
Barnyard	0.33	4.2	0.1	0	-	-	-	-
Kodo	0.15	2.0	0.09	0	-	23.1	-	-
Sorghum	0.38	4.3	0.15	47	0.21	20.0	1.25	12.0
Bajra	0.38	2.8	0.21	132	-	45.5	1.09	19.0
Rice	0.41	4.3	0.04	0	-	8.0	-	-
Wheat	0.41	5.1	0.1	64	0.57	36.6	-	-

(Source : Nutritive value of Indian foods, NIN, 2007; MILLET in your Meals, http://www.sahajasamrudha.org/).

Table-4 : Essential Amino acid profile of Millets (mg/g of N).

Millet	Arginine	Histidine	Lysine	Tryptophan	Phenyl Alanine	Tyrosine	Methionine	Cystine	Threonine	Leucine	Isoleucine	Valine
Foxtail	220	130	140	60	420	-	180	100	190	1040	480	430
Proso	290	110	190	50	310	-	160	-	150	760	410	410
Finger	300	130	220	100	310	220	210	140	240	690	400	480
Little	250	120	110	60	330	-	180	90	190	760	370	350
Barnyard	270	120	150	50	430	-	180	110	200	650	360	410
Sorghum	240	160	150	70	300	180	100	90	210	880	270	340
Bajra	300	140	190	110	290	200	150	110	140	750	260	330
Rice	480	130	230	80	280	290	150	90	230	500	300	380
Wheat	290	130	170	70	280	180	90	140	180	410	220	280

Source : Indian Food Composition Tables, NIN–2017 and *Nutritive value of Indian foods, NIN–2007.

Chandra 2005. Gluten is the most important protein in kodo millet (Sudharshana,et al.,1988) which is suitable for dough making. The millet protein has well balanced amino acid profile and good source of methionine, cystine and lycine (Table 3).

Barnyard millet is versatile crop that is raised for both fodder and food. It is Good source of phosphorus and dietary fiber (13.5g/100gm) which can be digestible mostly. Good source of iron and mineral matter. Little millet consists of (10.3%) of phenolic content when differentiated with others like (7.2%) in ragi and (2.5%) in foxtail millet which overcomes the risk of breast and colon cancer in animals. Highest fat content is found in little millet (4.7%) next t o bajra (5%).

Sorghum is minimum resistant to disease and pests. Sorghum is considered as an energy crop due to the high yields and its capacity to tolerate drought. Vitamin B-complex is in sorghum and D, E, K which are fat soluble. Beta carotene a pre-cursor of vitamin A of minimal amount is available in few varieties like having yellow endosperm. These are gluten free according to Taylor and Emmambux, 2008. But millets lack in vitamin A and traditional breeding is not possible so golden rice is used where this is possible .

Bajra comprises of good amount of protein (11.6%). Pearl millet digestible energy is low (85 -89), in relation to other millets (95-96.1) . The fat content is highest compared to others (5%). It consists of greater dietary fibre content (20.8%) in difference to others (Kamath and Belvady). It provides carbohydrates (67%), iron (8mg), energy (361 K.cal) and ample amount of phosphorus. It grows well in less fertile, water scarce, high temperature conditions. Cultivated well in saline and acidic soils. It is cultivated in Africa and tropical regions of India.

Nutrients bioavailability from millets

Nutrients availability in millets is lowered with the presence of some phytochemicals (tannins, phytates, phenols) and they have negative impact on digestibility, mineral absorption capacity . It can be reduce by traditional or home cooking techniques like cooking, soaking, milling and germination etc. these methods reduces anti – nutritional factors like tannins, phytates and activity of trypsin inhibitors and make them readily absorbed in our body after digestion (bioavailability of minerals).

Newly acquired life-styles has now given us diabetes, hypertension and cardiovascular disease

Table-5 : Properties of Dietary Fiber and their Health consequences.

Function	Health consequences	Millet
Water absorbing and bulking property	Energy diluents to formulate low calorie diets	All Millets
Increased transit time of food in the gut	Reduced risk of inflammatory bowel disease.	Sorghum and Finger Millet
Bile acid and steroid binding	Hypocholestero-laemic activity and reducing the risk of cardiovascular diseases	Pearl Millet, Sorghum and Finger Millet
Retardation of carbohydrate absorption and impaired glucose tolerance	Management of certain type of diabetes	Sorghum, Pearl Millet and Finger Millet
Binding of toxins	As a detoxifying agent	Sorghum
Binding of divalent cations	Reduced bioavailability of Ca, Mg, Zn, Fe	Proso Millet and Foxtail Millet (unprocessed)

Reference : Nutritional and Health Benefits of Millets, ICAR–INDIAN INSTITUTE OF MILLETS RESEARCH (IIMR) Hyderabad (2017).

running rampant. For the above diseases millets have returned as a viable option to live healthy life without consuming loads of anti-diabetic and anti-hypertension medicines that are not only very expansive but also have serious side-effects in the long run. Minor millets also act as a prebiotic feeding micro-flora in our inner ecosystem. Minor millets will hydrate human colon to keep us from being constipated. The high levels of tryptophan in minor millet produce serotonin, which is calming to our moods. Magnesium in minor millet can help reduce the effects of migraines and heart attacks. Niacin (vitamin B3) in millet can help lower cholesterol. Minor millet consumption decreases Triglycerides and C-reactive protein, thereby preventing cardiovascular disease. It is well known that germplasm resources are rich source of useful genes and have been successfully used in traditional breeding efforts to improve several crop plants.

Summary and Conclusion

Millets have several agrarian importances than staple cereals in terms of productivity and climate susceptibility. Millets have good grain qualities suitable for processing. Processing of the grain for many process involves primary (wetting, dehulling and milling) and secondary (fermentation, malting, extrusion, flaking, popping and roasting) operations. In addition, dehulling causes nutrients loss. All the Millets can be milled by hand grinding (household level) or machine milling (cottage, small-to-medium scale service and large scale industrial).

In the infant weaning food sector, in spite of unlimited potential, progress has been slow, as the installed capacity for industrial malting is limited. For instance, in the nonalcoholic beverage and weaning food sectors, storage quality of the grain, nutritional losses after processing, high cost of imported equipment and variation among cultivars are some of the problems militating against improved utilization of millet in the developing countries. However, more research needs to be carried out not only to develop a novel method of processing but also in examining the minerals bioavailability of millet based food through *in vivo* studies. Thus, the paper concludes with the recommendation of increasing millet consumption for healthy life and sustainable environment.

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Chapter 13

Membrane Stability : A Physiological Parameter to Assess Stress Tolerance

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Introduction

Plants are subjected to a wide variety of biotic and abiotic stress since they are sessile organisms. As one of the most important elements of biological membranes in all plant tissues, lipids play a significant part in how plants react to stressors. As a defence against diverse abiotic and biotic challenges, lipid characterisation is a successful adaptation technique for plants. It becomes essential for enhancing plant acclimatisation to various environmental adversities. Sphingolipids, sterols, and glycerolipids are the three main categories of lipids found in plant membranes. A fatty acid amidated to a long-chain base (LCB) with a polar head connected to the alcohol residue makes up the ceramide backbone of sphingolipids. Sphingolipids are considered as fundamental membrane building blocks in plants, affecting membrane permeability and integrity. Plant cells contain at least 500 distinct sphingolipid molecular species (Mittler 2002). As a result, one of the first places to experience damage from stress is the plant cell membrane, and plants' skill to keep this membrane intact is crucial to their ability to withstand stress. As a result, the membrane stability index is frequently used to evaluate the ability of crop plants to withstand stress. The strongest indicator for selecting resistant genotypes is the membrane stability index, especially in the early stages of plant development (Blum and Ebrecon 1981). Membranes act as the first live barrier to incoming signal molecules and are essential for cell viability. This cell component controls molecular trafficking, which aids in preserving cellular redox equilibrium. In addition to possessing vast endomembrane systems, eukaryotic cells are unique in that they have cell membranes. This leads to or restricts cellular compartmentalization as subcellular organelles. As in plastids and mitochondria, some organelle membranes create a dense intra-membrane network to increase their functional efficiency. However, under abiotic stress, cellular membranes' ability to maintain a buffering environment is severely compromised. Cell membranes encounter stress signals even though they serve as a check barrier in the initial stage. Their ability to effectively control the input and outflow of charged and neutral metabolites in response to stress signals is reflected in membrane composition, fluidity, and permeability (Kocheva *et al.* 2014).

The ultrastructure of chloroplasts eventually shows signs of damage from stress, which leads to the deterioration of cell membrane systems. In a wheat experiment, it was discovered that stopping irrigation for 15 days 73% decreased the membrane stability index (MSI). According to several researchers (Jamali et al. 2015; Venkateswarlu *et al.* 1993), plants including wheat, bananas, and strawberries that are under water deficit stress experience significantly lower MSI levels during droughts. In *Nigella sativa* plants, a lack of soil moisture increased electrolyte leakage into the intercellular space, which significantly reduced membrane stability. A lower MSI indicates a higher level of lipid peroxidation, which is brought on by increased oxidative stress brought on by the decrease of turgidity in cells during water shortages. A decrease in cell membrane stability, according to Landjeva *et al.* (2011), makes the membrane more permeable and increases electrolyte leakage from the cell. According to Bandurska and Gniazdowska-Skoczek (1995), the deterioration of membrane structure and function under osmotic stress is caused

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by a decrease in cell water potential. In such a scenario, excessive ROS production can exacerbate photoinhibition and result in electrolyte leakage, which in turn causes harm to the biological membrane system. Consequently, one of the main causes of damage and decreased integrity of the cell membrane during stress can be attributed to peroxidation of membrane lipids caused by ROS. Malondialdehyde (MDA), the breakdown product of lipid peroxidation in cellular membranes, is used to gauge the extent of lipid peroxidation. Numerous plant species have shown greater stress resistance when MDA is kept at lower levels. This makes it a valuable gauge for assessing the frequency of oxidative membrane damage. In earlier research, greater MDA accumulations were seen in bread wheat, maize, and gram genotypes under osmotic stress. Through the activation of harmful chemicals that attack the fatty acid chains in the thylakoid membrane, environmental stressors can cause lipid peroxidation. According to Baroowa and Gogo (2012), this speeds up the synthesis of MDA and causes harm to the membrane system as a result. One of the byproducts of polyunsaturated fatty acid peroxidation in cells is malondialdehyde (MDA). The overproduction of MDA is brought on by an increase in free radicals. Plants utilise malondialdehyde measurement to detect membrane lipid peroxidation. MDA content is widely used as an indicator of damaged plant membranes. If MDA levels are permitted to remain high, proteins and nucleic acids will undergo irreversible alterations. If MDA elimination and redox signalling modulation work as planned, MDA accumulation may be adaptation mechanisms rather than harm. According to Blum and Ebercon (1981), MDA can have a beneficial effect on a plant's development and defence (defence and reproduction) by activating regulatory genes and providing cell protection from oxidative stress.

Membrane fluidity

Temperature and lipid content both affect how fluid the lipid bilayer should be. The fluidity of membranes tends to increase as temperature rises. Free-flowing membranes become stiffer as the temperature is lowered. Phase transition describes this situation. The component fatty acid residues' chain length and level of unsaturation both affect fluidity. Phase transition occurs at a lower temperature for lipids with short or unsaturated fatty acyl chains than for lipids with long or saturated chains. The fluidity of membranes is also significantly influenced by cholesterol. Cholesterol obstructs phospholipid fatty acid chain motion at high temperatures, decreasing the fluidity of the membrane. Cholesterol keeps membranes from freezing at low temperatures. Second, in response to abiotic stressors, membrane lipid remodelling maintains lipid dynamics and membrane protein functionality. Changes in lipid class composition and the degree of unsaturation (number of double bonds) in fatty acyl groups are two examples of lipid modification types. Fluidity and integrity of membranes are directly impacted by these changes. The ability of various lipid classes to sustain or generate hexagonal II (HII) phases or bilayer structure varies. In order to retain the best fluidity and integrity of the membranes, plants attempt to reduce the degree of unsaturation at high temperatures, whereas the trend is the opposite under freezing stress (Bajji et al. 2002).

Role of membrane lipids in stress tolerance

Salt stress : The level of salt concentration and the kind of tissue determine how much the overall amount of membrane lipids change. In salt-sensitive plants, increased electrolyte leakage of membranes is caused by salinity and is correlated with a decrease in total lipid content, indicating a loss of membrane integrity. Increased lipolysis, peroxidation, and an obstruction of the lipid production pathway are all effects of stress that lead to a decrease in the overall amount of lipid in the membrane. Salt-sensitive cultivars see a decrease in lipid content under salt stress, but salt-tolerant species show no change (Guo *et al.* 2019).

Hypoxic conditions : Plants under the stress of hypoxia (oxygen depletion) have a significant change in membrane lipids. Overall, hypoxic stress reduces the overall lipid content, prevents lipid biosynthesis, and promotes lipid breakdown, which causes an overabundance of free fatty acids (Zhang et al. 2019). Changes in the composition of lipid classes, the degree of saturation, and the length of acyl chains are examples of lipid modifications. The function mechanisms in hypoxic stress, however, as well as the detail and systematic investigations about lipid alterations, are not well understood (Xu *et al.* 2020).

Low and high temperatures stress : In response to low-temperature stress, plant membrane lipids have a propensity to transition from a gel to a liquid-crystalline phase. The increasing degree of lipid desaturation is what causes this process. The fatty acid desaturases are the process's accountable elements. The amount of polyunsaturated fatty acids attached to the glycerol backbone is influenced by the activity of these enzymes, which in turn determines how sensitive the plant is to low-temperature stress. According to a profiling of lipid alterations in response to low temperatures, plants experience significant changes in membrane lipid composition (Liua *et al.* 2019). Unsaturated fatty acid content has been identified as a key indicator of cold tolerance. The ability to tolerate cold is improved by altering the proportion of saturated to unsaturated fatty acids.

Heat makes the plasma membrane more fluid and causes calcium to enter the cytoplasm through cyclic nucleotide-gated calcium channels. Heat stress causes the enzyme phosphatidylinositol phosphate kinase (PIPK) to become active. Additionally, lipid signalling molecules are produced in response to temperature stress. These lipids control how proteins behave, where they are located, and how active they are. This influx of calcium controls a calmodulin-binding kinase's activation, which in turn triggers the phosphorylation of heat shock transcription factors and the expression of genes downstream.

Methods to assess membrane stability : Different biochemical methods are employed to evaluate membrane stability, or functional permeability, which upon impairment results in cellular death. Using these techniques, we can quickly and efficiently test the membrane effectiveness of a vast collection of germplasm. Some of these actions include:

Electrolyte leakage : Cellular membrane alteration, which leads to function perturbation or complete dysfunction, is one of the most significant effects of environmental stress on plants. There is still debate on the precise structural and functional changes brought on by stress. However, increased permeability and ion leakage, which are easily assessed by the efflux of electrolytes, are well expressed signs of cellular membrane failure brought on by stress. As a result, cellular electrolyte leakage from damaged leaf tissue into an aqueous media is being used more and more as a screening tool for stress resistance to estimate membrane malfunction under stress. One of the most popular functional tests for figuring out membrane permeability is this one. The primary underlying premise of the leakage method is that "the higher the stress intensity, the greater the membrane injury," and thus the bigger the leakage. The threshold optimum for resistant genotypes with stable membranes is greater for stress level, and they can adjust by preserving membrane functionality and displaying less leakage. This method has a number of benefits, such as low cost, straightforward instrumentation (a conductivity metre), quick screening of a large collection of germplasm, etc. This physiological measure is frequently utilised in breeding material, despite the fact that it does not allow us to determine the contribution of each cellular compartment and the types of ionic species contributing to total leakage. The method of electrolyte leakage is divided into three steps viz., Washing, Incubation and Boiling (Fletcher and Drexlure 1980).

Leaf tissue is typically utilised to evaluate membrane permeability among all plant tissues since it is the centre of light perception and serves as a source site for photosynthesis. Less photosynthesis occurs when the membrane integrity of this plant tissue is compromised, which ultimately lowers crop plants' yield. The sample is cut into leaf discs or segments (10–20) of known length or diameter (1–2 cm) before being thoroughly cleaned with distilled water. Ions from surface-level injured cells are released as a result of washing treatment. Therefore, by this phase, the error's overall leakage contribution is decreased. To determine the amount of ion leakage, leaf segments are washed and then incubated for 24 hours in a known volume of deionized water. Leakage can be more or less depending on the extent of membrane damage. The initial conductivity (Ci), which is the conductivity of this solution containing leached ions, is measured following the incubation phase. The leaf segments are then autoclaved or cooked at 100° C for 2-3 hours with the ion leachate. Boiling causes membranes in tissue segments to leak, releasing all of the ions that were previously contained in the leachate solution. The conductivity of this solution is termed "final conductivity (Cf). Electrolyte leakage (%) is calculated as Ci/Cf x 100.

Lipid peroxidation : Lipid peroxidation is the series of oxidative lipid breakdown processes. Free radicals "steal" electrons from the lipids in cell membranes during this process, which damages the cells. A free radical chain reaction mechanism drives this activity. Due to the numerous double bonds and methylene bridges ($-CH_2$) that they include, polyunsaturated fatty acids are the ones that are most frequently affected because they have particularly reactive hydrogen atoms. When membranes are subjected to stress conditions, reactive oxygen species (ROS) are frequently formed, which reduces membrane function. These ROS trigger the generation of free radicals, which result in the peroxidation of membrane lipids. One such product created by the peroxidation of polyunsaturated fatty acids is malondialdehyde. When it reacts with thiobarbituric acid (TBA), whose absorbance can be measured at 532 nm, it produces pinkish-red chromogenicity. The absorbance value at 600 nm is deducted from the OD at 532 nm to prevent the absorbance by phenols, anthocyanins, sugars, etc. at 532 nm from being overestimated.

Procedure

Using a pestle and mortar, 100 mg of fresh leaf tissue is homogenised in 2 ml of 0.1% TCA. Centrifuging the homogenate for five minutes at 10,000 rpm. A 4 ml aliquot of 20% TCA containing 0.5% TBA is added to a 1 ml sample of the supernatant. After 30 minutes of heating at 95°C, the mixture is immediately chilled in an ice bath. After that, the reaction mixture is centrifuged for 10 minutes at 10,000 rpm. The result for the non-specific absorption at 600 nm is deducted after reading the supernatant's absorbance at 532 mm. The extinction coefficient of MDA, which is 155 mm/cm, is used to determine the concentration (Cheeseman 2006).

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Chapter 14

Applications of Polymer and Graphene Nanocomposites in Solar Photovoltaics

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Introduction

This chapter sums up the latest advancements in the improvement of graphene (G)/polymer nanocomposites to the amount of PSC applications. Graphene has appeared as a nanomaterial because of its versatility and unique properties, which are valuable for different device parts like active layers (ALs), transparent conductive electrodes (TCEs), and the interfacial layers (IFLs). Our emphasis will be on the preparation scheme of G/polymer nanocomposites, the photovoltaic (PV) properties of PSCs integrating these nanocomposites, graphene oxide (GO), and reduced graphene oxide (rGO), and the synthesis of G and its derivatives. Even though a large number of reviews about PSCs are presented, but literature reviews about G-based materials for solar-cell applications are insufficient to the best of our knowledge, and not any one of them targets the nanocomposites (Hoppe *et al.,* 2005; Cheng *et al.,* 2009).

G-based materials have been utilized in various layers of PSCs, e.g., ALs, TCEs, and IFLs. The the literature on this topic is so vast that only the most related examples concerning polymer/G nano-composites are discussed.

Graphene/Polymer Nanocomposites as Transparent Conductive Electrodes (TCEs)

For the replacement of traditional ITO electrodes in PSCs, G, and its derivatives have been applied as TCEs. With the help of flexible polymers like polyethylene terephthalate (PET), being a substrate, a lot of work has been accomplished. In this regard, by spin coating the materials over plasma conducted rGO/PET, the PV device was fabricated to make a hydrophilic surface, and rGO films that were synthesized by thermal annealing (TA) were deposited over PET. On the usage of rGO films with a transmittance of 65% and a thickness of 16 nm, a maximum of V_{oc} of 0.56 V, J_{SC} of 4.39 mA/cm^2, and PCE of 0.78% was obtained. Exceptionally, the device achievement could endure up to 1200 bending cycles without losing device performance, whereas the conventional cells covering ITO normally crack and decline upon bending because of the fragile nature of ITO. Quite upgraded performance (e.g., PCE of 3.05%) was acquired by depositing a rGO micromesh attained through a laser-pattering method onto PET, lower sheet resistance (565 ?/sq) of the rGO micromesh in contrast to pristine rGO, and impute to the superior transparency (59%). More significantly, this PSC has shown good bending stability and a commensurate PCE with ITO-based devices (3.82%). The high density of defects of these rGO-based electrodes that hinder device efficiency is its vital shortcoming (Thompson and Fréchet, 2008; Chen *et al.,* 2009).

The preparation of TCEs relied on sulfonated graphene (SG)/PEDOT composites processed by *in situ* polymerization as reported by Xu *et al.* (2009). SG was arranged from GO in four stages: (i) reduction of GO with $NaBH_4$; (ii) sulfonation with the aryl diazonium salt of sulfanilic acid; (iii) post-reduction with N_2H_4; and (iv) functionalization with sulfanilic acid, $NaNO_3$, and azoisobutyronitride (AIBN). Afterward, SG was dislodged in water pursued by the inclusion of the monomer EDOT and $Fe_2(SO_4)_3$. For 48

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hours at 50°C, the mixture was mixed and later poured into methanol. The overabundance of EDOT and other impurities were extracted via many washing cycles. Good processability was shown by the composites both in water and organic solvents, high thermal conductivity, superior transparency, and thermal stability. For films having a few nm thicknesses, transmittances greater than 80% in the 400–1800 nm wavelength range, and a conductivity of 0.2 S/cm were noticed. As compared to the conductivity of a commercial PEDOT: PSS product (10^{-6}–10^{-5} S/cm), this conductivity is much higher. Furthermore, a poly (methyl methacrylate) (PMMA) sheet coated with the mentioned composite was angled inward, even though it still maintained high electrical conductivity (0.18 S/cm) (Figure-1).

without the demand for surfactants. This approach incorporates the fixed backbone of PEDOT and strong ð-ð interactions within rGO sheets, and intermolecular electrostatic repulsions surrounded in negatively charged PSS bound and the RGO sheets, which transmit colloidal stability to the arising hybrid nanocomposite of rGO/PEDOT. A conductivity of 2.3 k?/sq and a transmittance of 80% were exhibited by the film. Additionally, its conductivity was nearly maintained following 100 bending cycles (Green, 1981; Dennler *et al.,* 2009). Recently, in inverted PSCs that were fabricated by spray coating, a 4-layered CVD-doped G employed with PEDOT: PSS was practiced as a cathode. The active layer was made up of phenyl-C71-butyric acid methyl ester ($PC_{70}BM$) being an acceptor, and poly[(5,6-difluoro- 2,1,3-

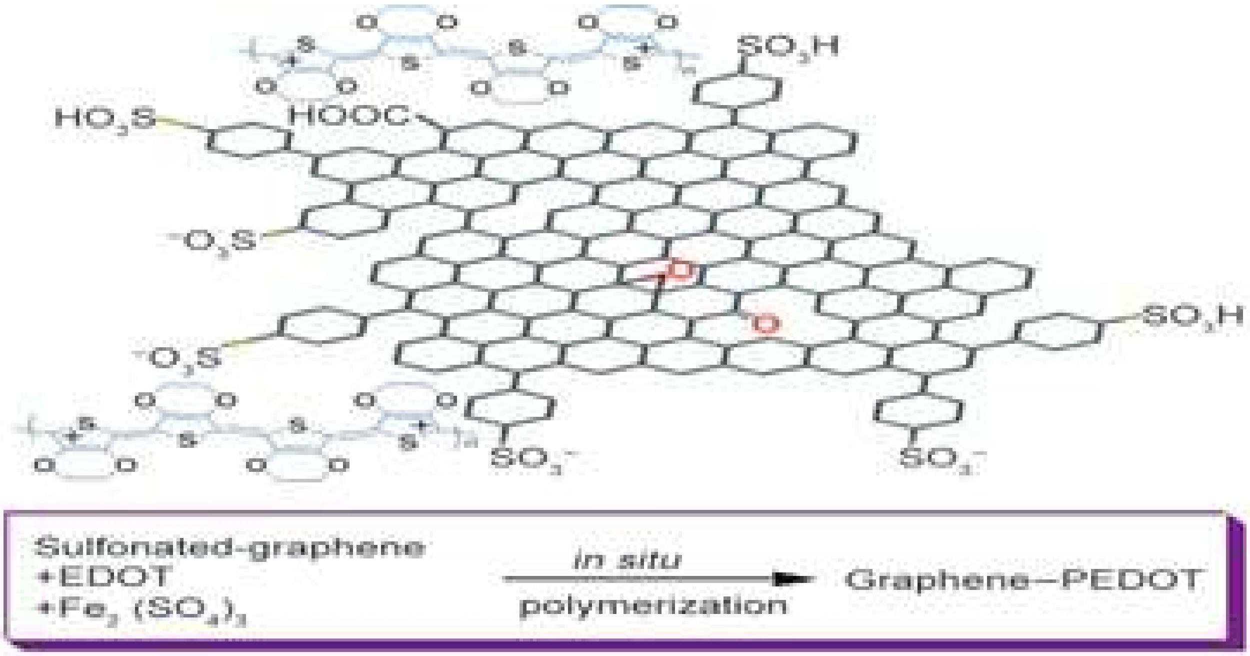

Figure-1 : Systematic explanation of sulfonated graphene (SG)/poly (3,4-ethylenedioxythiophene): Poly(styrene-sulfonate) (PEDOT) nanocomposite along with its synthesis-reaction conditions (Xu et al., 2009).

The preparation of a G-based composite electrode was done by spin coating a blended solution of PEDOT:PSS and surfactant functionalized G, with the altered G sheets evenly dispersed in the PEDOT: PSS matrix. The transparency and conductivity of this TCE were able compared to those of an ITO electrode. More significantly, it can be bent over 1000 cycles with just a 5% growth in its resistance and it has shown high stability (both electrical and mechanical). Still, the existence of the surfactant stabilizer is unwanted from an application perspective. It was found that an aqueous G suspension stabilized by PEDOT: PSS was synthesized by Jo *et al.* (2011) via the chemical devaluation of GO in the existence of this polymer,

benzothiadiazol-4,7-diyl)-alt-(3,3"'-di(2-octyldodecyl)2,2';5,'2";5,"2"'-quaterthiophen-5,5"'-diyl)] (PffBT4T-2OD) being a donor. The resulting device demonstrated a PCE of 2.8%, V_{oc} of 0.72 V, FF of 0.37, and J_{sc} of 10.5 mA cm^{-2}, respectively, not much from the related figures of an ITO-based cell. The vibration-assisted ultrasonic spray coating has prepared G-doped PEDOT:PSS nanocomposites which are a fast, single-step, and scalable process. The resulting films offered an utmost electrical conductivity of 298 $S \cdot cm^{-1}$, with transparency able to compare to that of ITO-coated glasses, approximate a 10-fold increase in contrast to pristine PEDOT:PSS films. From when the G sheets bridge within the

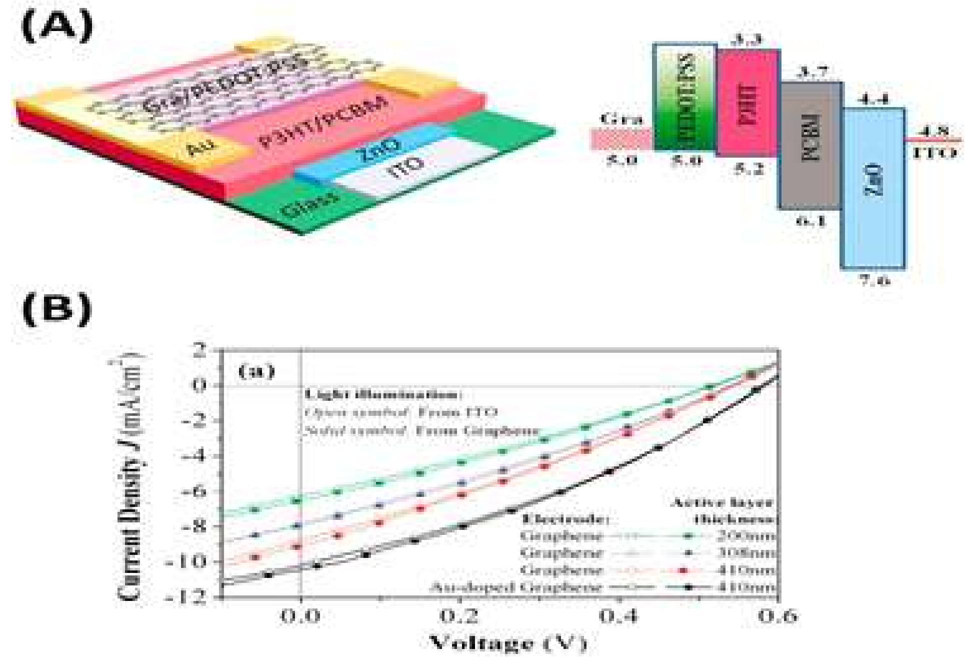

Figure-2 : (A) Band structure and diagrammatic depiction of a PSC with the structure glass/indium tin oxide (ITO)/ZnO/P3HT:PCBM/Au/PEDOT:PSS/G; (B) J-V characteristics evaluated from two sides of the PSC using G top electrode and various active layer thicknesses.

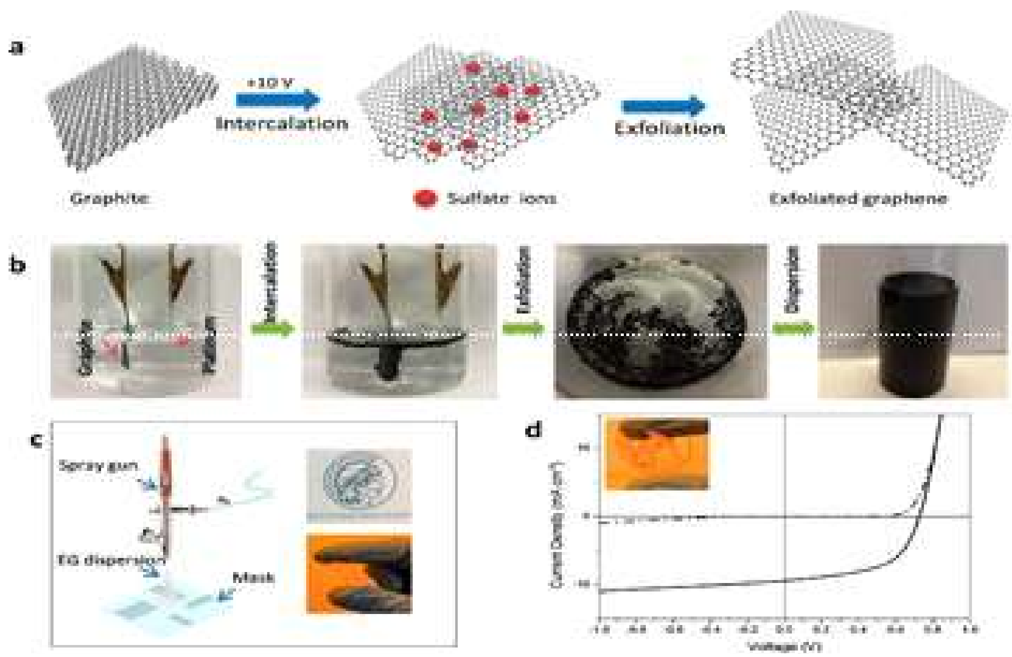

Figure-3 : (a) Plan of the electrochemical exfoliation of graphite; (b) optical figures of the exfoliation process; (c) diagrammatic portrayal of spray deposition of exfoliated graphene (EG) dispersion over poly (ethylene 2,6-naphthalate) (PEN); (d) J-V properties of the cell under dark (dashed line) and light conditions (solid line).

PEDOT:PSS rings through strong ð-ð interactions that serve as high-mobility channels, this remarkable progress was attributed to the higher carrier concentration and carrier mobility. Moreover, the number of defect sites in PEDOT:PSS is reduced by the ð-ð interactions. More significantly, the energy level of G-doped PEDOT:PSS films showed superior mechanical properties involving hardness and wear resistance, better stability, and could be tuned (De Kok *et al.,* 2004; Luo *et al.,* 2009).

It was developed by layer-by-layer electrophoretic deposition. The resulting device gave J_{sc} of 0.42 mA·cm^{-2}, a PCE of 0.92%, a V_{oc} of 0.48 V, and FF of 0.23, respectively, which were greater than those of devices having ZnS- or PPy-modified electrodes. The PV efficiency was improved by the nanocomposite

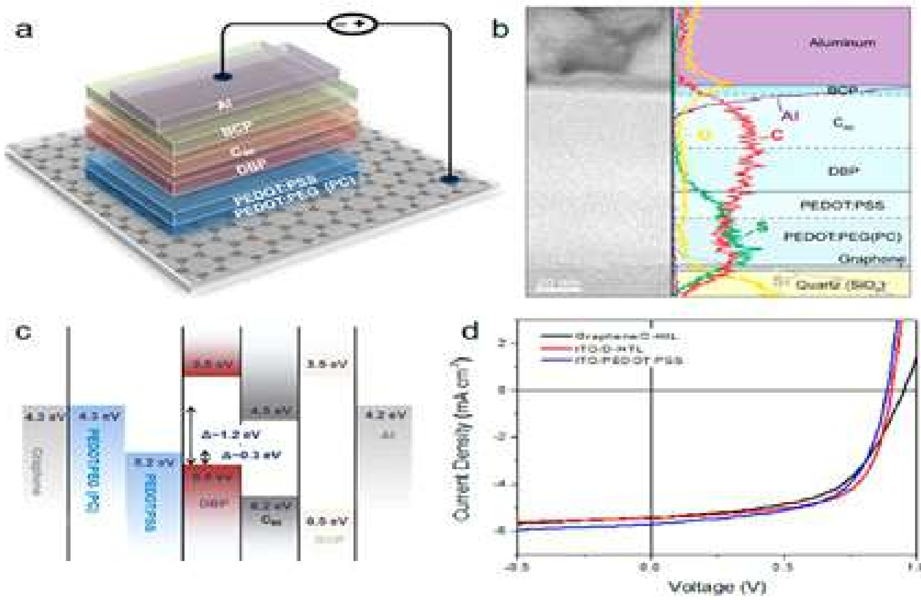

Figure-4 : (a) Diagrammatic description of the PSC with G anode and structure G/PEDOT : PEG(PC)/ PEDOT:PSS/DBP/C60/BCP/Al; (b) cross-sectional transmission electron microscope (TEM) image (that is on left side) of the device represented in (a), with an energy-dispersive line scan on a figure of the device cross-section (that is on right side); (c) flat-band energy level chart of the PSC; (d) J-V properties of the G-based device (red lines) in contrast with ITO reference cells (blue lines).

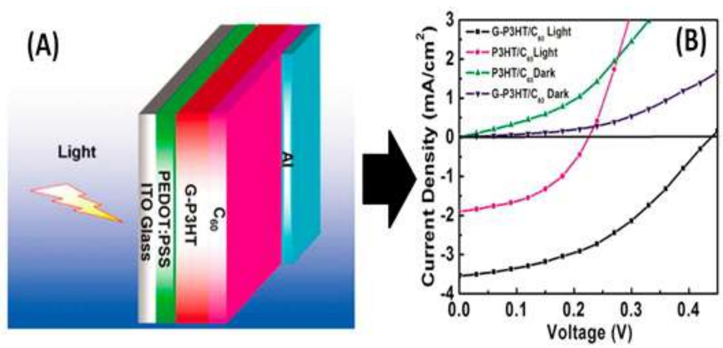

Figure 5. (A) Graphical image of ITO/PEDOT : PSS/G-P3HT:C_{60}/Al PSC; and (B) J-V properties with P3HT:C_{60} or G-P3HT:C_{60} being the active layer.

because ZnS nanoparticles (NPs) operated as bridges, PPy served as a hole acceptor and a remarkable sensitizer, while G enacted as a phenomenal conductive transporter and collector.

Semitransparent PSCs were fabricated by Liu *et al.* (2012) that were based on P3HT: phenyl-C61-butyric acid methyl ester ($PC_{61}BM$) by a CVD-grown single-layer G film doped with ITO as the bottom electrode and PEDOT:PSS and Au NPs as the top electrode. An increase in conductivity has resulted from the use of the doped G electrode which is approximately 400% as compared to pristine G, and a maximum PCE of 2.7% was obtained on the illumination from the G side, which was associated with the improved transmittance of the G electrode. PSCs with higher efficiency are anticipated to be obtained with the usage of the single-layer G with superior quality and by optimizing the processing conditions (Figure-2) (Yun *et al.,* 2011).

Another flexible PSC was fabricated by some researchers on polyimide (PI) substrates having multilayer CVD G doped with P3HT:$PC_{61}BM$ as ALs and Au NPs and PEDOT:PSS as top TCE (Taleghani *et al.,* 2009; Walker *et al.,* 2011).

A maximum PCE of ~3.2% was shown by the device with a structure of G/Au/PEDOT : PSS/P3HT : PCBM/ZnO/Ag/PI, which was reduced merely by around 8% subsequent to 1000 bending cycles, signifying impressive stability and flexibility. It was found, more considerably, that air could not spread out over the fine space within the G layers, therefore giving a great packaging effect to flexible SCs. Multilayer G can serve as an environmental obstruction and shield the PSCs from air pollution,

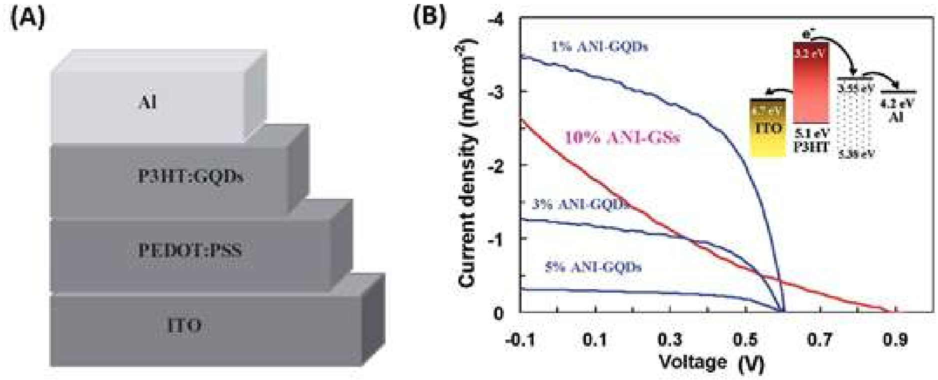

Figure-6 : (A) Scheme-wise representation; and (B) J-V curves of ITO/PEDOT:PSS/P3HT:GQDs/Al device formed on aniline-modified GQDs with various GQDs content.

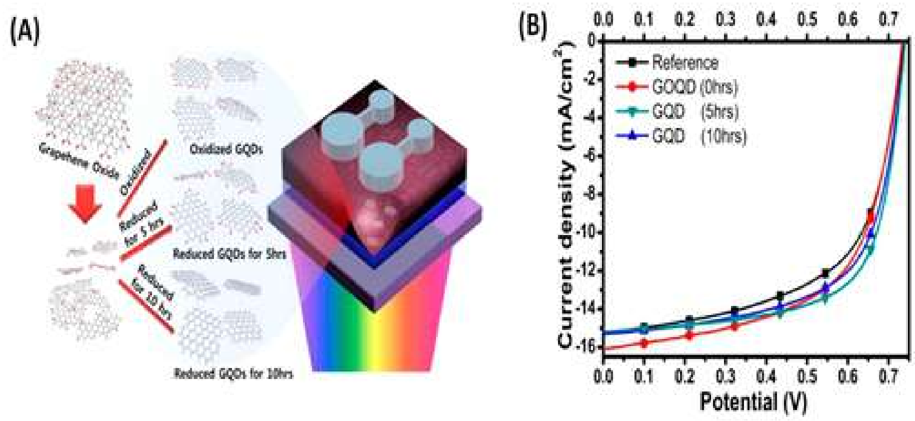

Figure-7 : (A) Diagrammatic view of the synthesis of reduced graphene oxide quantum dots (rGOQDs) and graphene oxide quantum dots (GOQDs), where the edge functional groups are regulated by controlling the thermal reduction time; (B) J-V curves of the PSCs with various kinds of GQDs.

which minimizes the related costs and simplifies the device fabrication (Das *et al.,* 2015).

In recent times, G was formed through electrochemical exfoliation of graphite with a method that intercalated sulfate ions. The processed exfoliated graphene (EG) films were sprayed onto flexible poly (ethylene 2,6-naphthalate) (PEN), and after that, the composite was used as an anode in PSCs. The device applying PTB7:$PC_{71}BM$ being the active layer attained a PCE of 4.23%, which was retained after 150 bending cycles. This solution-treated G-based electrode had a low sheet resistance of 0.52 k?/sq, and a transparency of 70% and was mechanically sturdy, without altering resistance at various bending angles (Figure-3) (You *et al.,* 2013).

Another device was established by An et *al.* (2014) covering a PMMA/G composite as an anode. The polymer was spin-coated upon highly uniform G formed by CVD, leading to a bilayer composite that was again deposited over a flexible PET substrate. The PMMA made better the adhesion of G upon the substrate, hindering both crack formation and contamination. Because of this novel introduced process, the G sheet resistance was minimized by around 50% at the same transmittance, turning to a device with a structure: PET/PMMA-G/MoO_3/PEDOT:PSS/Poly[*N*-9`-heptadecanyl-2,7-carbazole-alt-5,5 (4`,7`-di-2-thienyl-2`,1`,3`-benzothiadiazole)] (PCDTBT): $PC_{70}BM$/Ca/Al which showed J_{sc} of 8.88 mA cm^{-2}, a PCE of 3.3%, a V_{oc} of 0.83 V, and FF of 0.45, approximate of 200% higher efficiency in contrast to the reference cell without G (Figure-4).

3. Graphene/Polymer Nanocomposites as Active Layers (ALs)

At first, the structure of OSCs was similar to that of traditional SCs: a single flat semiconductor heterojunction that was composed of a film of acceptor and a thin layer of active polymer (donor), intervening between two electrodes. The field formed in the donor-acceptor (D-A) interface is effective for exciton dissociation within free electron-hole pairs. Because of the reduced interface area, the PCEs of OSCs formed on this structure is very low. In other words, only excitons created nearest to the interface (i.e., just a few nm) can be detached into free-charge carriers. Hence, flat heterojunction OSCs should be thin, which causes low J_{sc} and poor light absorption (He *et al.,* 2012).

Later, most OSCs were developed with undoubtedly higher PCE which was based on the BHJ structure (Wan *et al.,* 2016). In this kind of cell, there is a creation of an interpenetrating network in the active layer having nanoscale phase separation (comprising of a fullerene-derivative acceptor and a polymer donor). The improvement of PCE in BHJ SCs in contrast with those of in bilayer SCs is chiefly because of the more adequate exciton dissociation permitted by the increased charge-carrier collection and the maximized heterojunction interface as a result of the creation of the interpenetrating network. In this view, the 2D structure of G and the vast specific surface area assist the composition of a bicontinuous interpenetrating network of acceptor and donor materials towards the nanometer scale.

The first usage of solution-processable G functionalized with poly(3-octylthiophene) (P3OT) being a donor and phenyl isocyanate being an acceptor in PSCs was reported by Liu and his coworkers (Chen et al., 2015). The device, having an ITO/ PEDOT:PSS/P3OT:G/LIF/Al architecture, produced the highest PCE of 1.4% toward a G content of 5 wt.% optimized by an annealing process (at 160°C, for 20 min). The same researchers used the same functionalized G in a maximum concentration (10 wt.%) being an acceptor and P3HT being a donor in a very much alike PSC (Lin et al., 2016), with the highest PCE of 1.1%, J_{sc} of 4.0 mA·cm^{-2}, FF of 0.38, and V_{oc} of 0.72 V, subsequent to an annealing treatment for 10 min at 160°C. The progress of the device performance was interpreted with the consideration of the increase of the exciton dissociation area because of the speedy electron transport via G. Still, annealing at maximum temperatures (i.e., 210°C) prompted a reduction in the PCE (0.57%). Wang et al. (2011) developed a similar PSC applying a P3OT/solution-processable G composite being the active layer. The device exhibited a J_{sc} of 4.6 mA·cm^{-2}, a PCE of 1.14%, FF of 0.37, and V_{oc} of 0.67 V. Other researchers formed a P3HT/solution-processable G/functionalized multiwalled carbon nanotubes (f-MWCNTs) nanocomposite, where G served as a percolation path for the electrons and an electron acceptor, P3HT enacted as an electron donor, and the f-MWCNTs gives percolation paths of holes (Sun *et al.,* 2015). The consequent device having the structure: ITO/PEDOT : PSS/P3HT-f-MWCNTs-SPFGraphene/LiF/Al produced a PCE of 1.05%, V_{oc} of 0.67 V, FF of 0.32, and a J_{sc} of 4.7 mA·cm^{-2}. However, the PCE of these cells among solution-processable G is pretty low, and could probably be made better by tuning the processing conditions and G content; still, for G-based PSCs, the theoretical studies envision an efficiency exceeding 12%. The CH_2OH-terminated regioregular P3HT was grafted by Yu *et al.* (2010) at the COOH groups of the GO surface using an esterification reaction. It was found that the consequent P3HT-grafted GO sheets were soluble in many organic solvents, which is

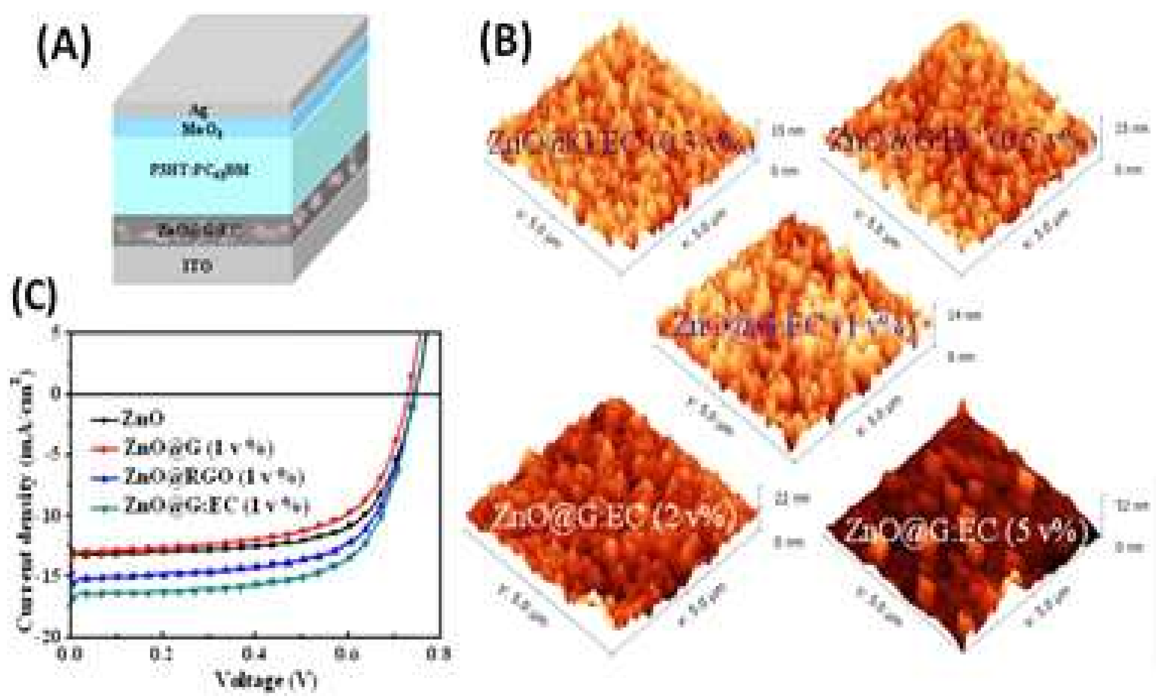

Figure-8 : (A) Graphical illustration of ITO/ZnO@G : EC/P3HT:PC$_{61}$BM/MoO3/Ag device; (B) atomic force microscope (AFM) pictures of ZnO@G:EC nano- composites with various G contents; (C) J-V curves of PSCs with various nanocomposites.

worthwhile for solution processing. They utilized P3HT-*g*-GO/C_{60} being the active layer to construct a PV device having architecture: ITO/PEDOT: PSS/G-P3HT:C_{60}/Al, depicting a PCE of 0.61%, which is approximately 200% improved in contrast to the device based on P3HT/C_{60}, therefore, the chemical grafting of P3HT upon G can improve light absorption and electron delocalization (Figure-5) (Wallace, 1947; Chang and Wu, 2013).

For opening the bandgap of the graphene, a very persuasive approach is to convert 2D G into 0D quantum dots (GQDs). Additionally, the GQDs are soluble in organic and aqueous solvents and rich in oxygenated groups, hence enabling more functionalization. GQDs having sizes 3–5 nm were utilized as electron-acceptors in a device that has the structure of ITO/PEDOT:PSS/P3HT:GQDs/Al, they were synthesized using an electrochemical approach, resulting in a PCE of 1.28% and a V_{oc} of 0.67 V. A PCE of 1.14% is obtained from the aniline-modified GQDs that were prepared using a hydrothermal method and utilized as acceptors in PSCs where P3HT was acted as a donor. GQDs that were derived from double-walled carbon nanotubes have also been processed by a solution-based approach and included an active layer of P3HT:PCBM, generating a PCE of 5.24%. The latest method to enhance the efficiency of PSCs is P3HT:PCBM:GQDs ternary composite (Figure-6) (Weiss *et al.,* 2012; Wei *et al.,* 2016).

Reduced graphene oxide quantum dots (rGOQDs) and graphene oxide quantum dots (GOQDS) have been mixed with a PTB7:PC_{71}BM active layer to improve the charge-carrier extraction of PSCs and optical absorptivity, turning to a device having the structure: ITO/PEDOT:PSS/ GOQDs:PTB7:PC_{71}BM/Al. An increase in both FF and J_{sc} was noticed for rGOQDS, as a result of the oxygenated functional groups on the surface of the QDs and their better conductivity, turning to an utmost PCE of 7.6%. Doping with heteroatoms is another scheme that makes rise the bandgap of G (Zheng and Kim, 2015). Therefore, PSCs have been built up by integrating nitrogen-doped rGO into P3HT:PCBM ALs. The maximum PCE attained (4.5%) with this device (i.e., ITO/PEDOT : PSS/N-doped graphene:P3HT:PCBM/Al) was around 40% more compared to that of a device without G. In general, the efficiency of these PSCs with G-based materials is less compared to that of traditional cells combining C_{60} and its derivatives. Advance research should be conducted to optimize the device fabrication process to develop PSCs with maximum PCE and to regulate the structure and characteristics of G (Figure 7) (Nair *et al.,* 2008; Díez-Pascual *et al.,* 2015).

4. Graphene/Polymer Nanocomposites as Interfacial Layers (IFLs)

The IFLs that are the electron-transporting layer and hole-transporting layer within the anode/or cathode and active layer respectively, firmly condition the efficiency of PSCs. They are usually utilized for the improvement of the electrical contacts and the enhancement of the charge collection and transport. Moreover, IFLs can enhance radiation distribution and light absorption in the active layer and improve performance stability. Charge-carrier recombination is reduced by IFLs in electrodes by selectively permitting the wanted carriers to penetrate and restricting carriers from moving towards the opposite electrodes (Soltani-Kordshuli et al., 2016; La Notte *et al.,* 2018). This is significantly important in BHJ PSCs, where the acceptor and donor semiconductors are distributed randomly in the active layer. Hence, both semiconductors could approach cathode and anode, growing the probability of recombination. IFLs can be developed to attain less contact resistance at the electrodes, bypassing this specification to be satisfied at the active layer, which can be devised without that constraints. The absorption and light distribution in PSCs is improved by IFLs too by minimizing the reflection of light at interfaces (Wu *et al.,* 2008; Diez-Pascual and Diez-Vicente, 2016). Because of the advantages of the G and its derivatives that they have superior energy-band structure which gives less corrosion for the ITO electrode and efficient charge transport, they have been used in the role of both kinds of layers (Su *et al.,* 2011). As the hole transport layer, a GO/PEDOT:PSS composite was utilized in a PCDTBT:PC_{71}BM-based BHJ PSC, resulting in a PCE of 4.28%, which is more compared to devices using either PEDOT:PSS or GO as hole transport layers (PCEs of 3.57% and 2.77%, respectively). Additionally, increased stability and reproducibility were noticed. The enhanced performance was attributed to the well-matched work function of PEDOT:PSS and GO that minimized series resistance and maximized charge carriers' mobility. Apart from that GO could effectively limit the electrons because of its high bandgap of ~3.6 eV, resulting in a maximized shunt resistance (Dreyer *et al.,* 2014; Carrasco-Valenzuela *et al.,* 2017).

A PEG-modified Au NPs/GO nanocomposite was developed as the hole-transport layer within a device having the structure: ITO/PEDOT : PSS (Au @ PEGGO)/PBDTTT-CT by Chuang and Chen (2015). The solubility of the nanocomposite was improved by PEG, so it was well diffused in different organic solvents and water. A comparably maximum PCE of 7.26% was obtained. Except for that, when the nanocomposite was arranged at various locations, various spectral-enhancement regions were found to expose several dielectric environments adjoining the NPs, which could be advantageous for progressing the broadband absorption of solar irradiation (Eda and Chhowalla, 2010; Chen *et al.,* 2013).

A polyacrylonitrile-grafted rGO (PRGO) nanocomposite was synthesized by Jung *et al.* (2017) that was enacted being a hole-transport layer in PSCs formed on PTB7-Th. A covalent strategy was used for the fabrication of the nanocomposite based on graft polymerization with styryl-functionalized GO and acrylonitrile, and *in situ* radiation-induced reduction. It presented good electrical conductivity (0.87 S/cm), homogeneous thin-film morphology, phenomenal weather stability, and high work function (4.87 eV). For the improvement of PV stability and efficiency, this combo of characteristics makes it appropriate as interfacial material in PSCs (Lima *et al.,* 2016). The resulting device displayed V_{oc} of 0.76 V, FF of 0.64, a PCE of 7.24%, and J_{sc} of 14.78 mA/cm^2, whereas the device based on PEDOT:PSS displayed V_{oc} of 0.78 V, FF of 0.66, PCE of 7.17%, and J_{sc} of 13.91 mA/cm^2. More significantly, superior durability was shown by it (Jo *et al.,* 2011; Pei and Cheng, 2012).

Hu *et al.* (2015) proposed a novel electron-transport layer based on ZnO nanocrystals diffused in a G matrix along with ethyl cellulose (EC) being a stabilizer. The ZnO@G:EC nanocomposites with several G contents displayed an almost smooth morphology, and maintained the initial actual structure of G with maximum conductivity. A PCE of 3.9% was given by the device based on P3HT:PC_{61}BM having the structure: ITO/ZnO@G : EC/P3HT : $PC_{61}BM/MoO_3$/Ag, which is around 20% maximum than that accompanying bare ZnO nanocrystals. Taking over the active layer by PTB7:PC_{71}BM, the PCE increased to 8.4%. For PSCs, this simple way can give highly conductive electron-transport layers (Figure 8) (Xu *et al.,* 2009; Konios *et al.,* 2015).

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Chapter 15

Insects as a Source of Biodiesel Production

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Abstract

Biodiesel is an important resource to provide energy for the world's transportation needs. Promotion of biodiesel, technology is not a limited factor, but the raw material of biodiesel. Insect-derived biodiesel could be a better choice compared to microorganisms to generate biodiesel. Moreover, the cost of feedstock is a major economic factor in the development of biodiesel.One of the ways is to reduce the costs of biodiesel by using the cheaper feedstock and insects are best alternative to this. The newest waste management technology is bioconversion using fly larvae converting organic waste to insect larval biomass and organic residue. Several biochemical products and by-products can be obtained, including insect-derived lipid, protein, and biodiesel (Mohd-Noor, S.-Net al 2017). Insects belonging to the order Coleoptera - such as the Yellow Meal Worm (YMW) Tenebriomolitor L., and Diptera - such as the Black Soldier Fly (BSF) *Hermetiaillucens* L. can efficiently degrade organic matters, transforming wastes into larval biomass. BSFL can convert around 58% of the dry matter within an organic source into high quality animal feedstuff. So it is concluded that the BSFL biomass residuals could be a potential protein source replacement and the fat accumulated in the bioconversion of organic wastes by insect can be used as feedstock for biodiesel production.

Key words : *Biodiesel, feedstock, bioconversion, biomass, Hermetiaillucens L.*

Introduction

Recycling organic waste material (biowaste) is still fairly limited, especially in low- and middle-income settings, although this is by far the largest fraction of all generated municipal waste. The newest waste management technology is bioconversion using fly larvae converting organic waste to insect larval biomass and organic residue (Rindhe, S.N.et al 2019). Several organisms have been used in this treatment process. Insects belonging to the order Coleoptera - such as Yellow Meal Worm (YMW) Tenebriomolitor L., and Diptera - such as the Black Soldier Fly (BSF) Hermetiaillucens L. can efficiently degrade organic matters, transforming wastes into larval biomass.

Black soldier fly larvae are favored due to their higher protein content and greater amino acid composition (Schiavone *et al* 2017). BSFL biomass also contains high protein (~40%) and lipid (~ 30%) sources, which could plausibly be used as aquaculture, poultry, and broilers feed (Diener *et al* 2015).

Black Soldier Fly (Hermetiaillucens Linnaeus)

*H. illucens*is native to the tropical, sub- tropical and warm temperate zones of America (Family: Stratiomyidae).

The adult fly is wasp-like and 15 - 20 mm long. (Hardouin *et al*., 2003). Primarily black, the female's abdomen is reddish at the apex and has two translucent spots on the second abdominal segment. The male's abdomen is somewhat bronze in color.

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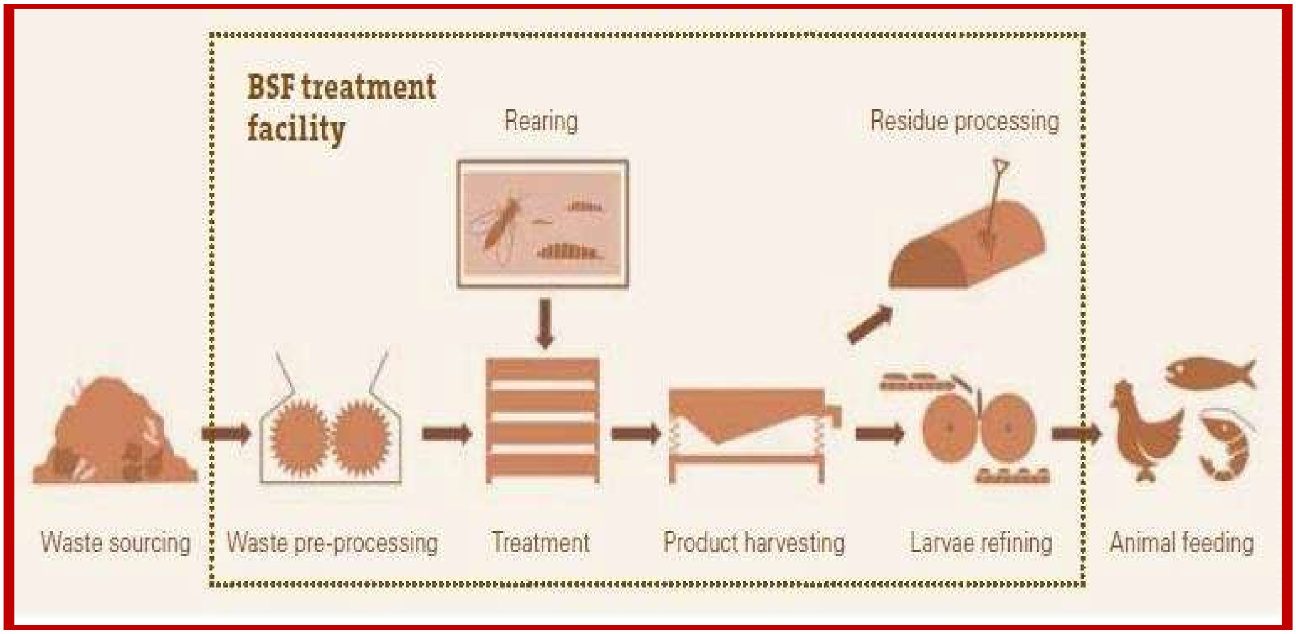

Layout of a BSF treatment facility (Two tons of Bio-waste per day)
Source: (St-Hilaire *et al.,* 2007)

They are generally considered a beneficial insect and non pest. The adult fly does not have mouthparts and doesn't even feed during its short lifespan. They do notn. bite or sting, feed only as larvae, and are not associated with disease transmissio

Rearing *H. illucens*has been proposed as an efficient way to dispose of organic waste, by converting them into a protein and fat-rich biomass suitable for various purposes, including animal feeding for all livestock species, biodiesel and chitin production (Van Huis*et al*., 2013; Diener*et al*., 2011; Li *et al*., 2011).

BSF rearing unit : This ensures that a reliable and consistent amount of small larvae (called 5-DOL) is always available to inoculate the daily amount of biowaste that is received for processing at the treatment facility. A certain number of larvae hatchlings are, however, kept in the rearing unit to ensure a stable breeding population.

Waste receiving and pre-processing unit : It is critical that the waste received at the facility is suitable for feeding to the larvae. A first step involves a control of the waste to ensure it contains no hazardous materials and no inorganic substances. Further steps then involve a reduction of the waste particle size, a dewatering of the waste if it has too high moisture and/or a blending of different organic waste types to create a suitable balanced diet and moisture (70-80%) for the larvae.

BSF waste treatment unit : This is where the 5-DOL from the rearing unit are fed with biowaste in containers called "larveros". Here, the young larvaefeed on the biowaste, grow into large larvae and, thus, process and reduce the waste.

Product harvesting unit : Shortly before turning into prepupae, the larvae are harvested from the larveros. The waste residue itself is also a product of value.

Post-treatment unit : Both products, larvae and residue, can be further processed if required by the local market demand. We call this "product refining". Typically, a first step will be to kill the larvae.

Other steps of larvae refinement can be to freeze or dry the larvae, or to separate larvae oil from larvae protein. A typical step for residue refinement is composting or feeding the residue into a biogas digester for fuel production.

Larva as bio-converter

There is a good opportunity to utilise these flies for bioconversion considering the fact that approximately 1.3 billion tonnes of food is wasted from the food produced each year in world (Gustavsson *et al.,* 2011).

The larvae modify the microflora of manure, potentially reducing harmful bacteria such as Escherichia coli 0157:H7 and Salmonella enterica (Van Huis *et al.,* 2013).

It has been reported that the larvae contain natural antibiotics which act on growth promoter in the animal feed (Newton *et al.,* 2008).

Comparison of nutritional value of black soldier fly larvae meals with conventional meal (Source: Makkar *et al.,* 2014

Constituents (% in DM)	BSF Larvae	Fish meal	Soy meal
Crudeprotein	56.9	70.6	51.8
Lipid	26.0	9.9	2.0
Calcium	7.56	4.34	0.39
Phosphorus	0.90	2.79	0.69
Ca : P ratio	8.4	1.56	0.57

Difference between BSF and Worm Composting.

Sr. No	Characteristics/Parameter	BSF	Worm composting
1.	Raw material	Any organic matter (biowaste/slaughter house waste/Egg shells/any manure etc.) High moisture products even more than 80 % moisture content	Consume only the bacteria generated by the decaying plant materials
2.	Temperature	Best results 25-35°C (tolerate even upto 40°C.More suitable in Indian conditions	Best results 10-15°C, dampness.
3.	Humidity	Low/even dry	High humidity 65- 85°C
4.	Process efficiency	Fat 20% digestion requires only 24 hr also known as Accelerator Slow process .	Initially you have to decay the plant material for 20 days by adding cow dung etc.
5.	Nutritive value as feed	BSF larvae have 35% protein, Good source of energy and can fulfil the requirement of Essential amino acids for poultry feed, easily digestible, Further these kill salmonella, so problem of Salmonellosis in poultry can reduced.	No such benefit
6.	Quality of product	Free from bad odour, smell	Free from smell and odour
7.	Biogas	Residues can be utilized in biogas plant	Cannot utilized
8.	Nutritive value of compost	Depend on the type of raw material. It provide much higher assimilated nitrogen than the vermicompost.	Av. Organic carbon: 9.5-17.98% Nitrogen: 0.5-1.5% Phosphorous 0.1-0.3%
9.	Economics/Cost of production	Cost effective lower period, initially availability is a problem however no sophisticated machinery nor skilled labour, process can be completed in 3-5 days.	Cost effective, Commonly used in India so availability of worms is not a problem, but process takes 45-60 days

Applications

Reduces food waste

Reduces animal feed costs

Improves fertilization

Black Soldier Fly Larvae (Scope)

Protein Meal

Biofertilizers

Larvae Oil

Future Prospects

Potential protein source for humans both in the future and in the developing world as they are edible, nutritious (especially when defatted).

BSF Larvae they are commonly used in household and manure composting in western countries since long time. The rearing of BSF is easier in India as larvae flourish more in tropical environment than in colder one, hence composting using BSFL should be recommended in India as well.

Conclusions

It can be concluded that the biodiesel production from insects developed on organic waste has great potential to satisfy the increasing demands for liquid fuels, particularly in developing continents (i.e., Asia, Africa, and Middle-east).

It will cut fossil energy consumption, relieve the impact on the environment, and reduce the cost of biodiesel.

Environmental problems like global warming can be reduced as the BSFL biomass residuals could be a potential protein source replacement and can be used as feed meal in aquaculture, poultry, broilers, as well as for human consumption.

India is a diesel deficit nation , so it becomes

Different types of biowaste found suitable for BSF treatment.

Municipal organic waste	Agro Industrial Waste	Manure and Faeces
Municipal organic waste	Food processing waste	Poultry manure
Food and restaurant waste	Spent grains	Pig manure
Market waste	Slaughterhouse waste	Human faeces

necessary to increase the production of biodiesel using the best alternative methods without any harmful effects on the environment and biodiesel is a good substitute for conventional diesel.

The recycling of organic waste is limited so this can prove to be the best possible method to reduce the waste without any need of sophisticated high end technology.

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Chapter 16

Improvement of Okra

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Introduction

In tropical and subtropical areas of the world, okra (*Abelmoschus esculentus* (L.) Moench), often referred to as bhindi, Lady's finger, or gumbo, is an annual vegetable crop raised for its immature fruits. Looking at okra's potential, advancement is imperative. Accelerated breeding has begun to gain popularity among breeders as a means of rapidly developing new varieties. Speed breeding in fully contained, controlled-environment growth chambers can accelerate plant development for research applications such as adult plant trait phenotyping, mutant inquiries, and transformation (Watson *et al*. 2018).

The current crop improvement rate using conventional breeding methods is insufficient to fulfil future population growth demands. To hasten the production of new varieties, speed breeding techniques must be established. Speed breeding may minimise generation duration and accelerate breeding and research projects (For example, in some crops like as peas, 6 generations are achieved in a single year). More than 99% of okra production occurs exclusively in underdeveloped Asian and African nations, with relatively low productivity, particularly in African countries (2.25 t/ha) compared to any other parts of the world (Mishra *et al*. 2017).

Okra has various production issues, including decreased seed germination during the summer season and blossom drop in okra at temperatures above 42 °C (Dhankhar and Mishra 2004). Diseases such as yellow vein mosaic disease and enation leaf curl disease, as well as fruit borer and root-knot nematode infestations, cause severe yield losses in okra. Despite the extensive variation accessible among wild relatives of okra, significant progress in overcoming these difficulties has not been accomplished due to hybridization restrictions.

Acceleration of Selection Generations in Traditional Breeding Methods

The pedigree method is the most extensively used means of breeding for improvement in okra, and it usually needs eight to ten generations to generate a homozygous genotype with acceptable attributes. At this rate of advancement, meeting global demand in a short period of time is tough. In comparison to cereal and oilseed crops such as rice, pearl millet, and mustard crops, speed breeding has not received much attention in vegetable crops, particularly okra. The possibilities for speeding up the typical breeding procedure are discussed further below:

I. Early Multi-site Trials
II. Flowering Regulation
III. Doubled Haploids
IV. Heterosis breeding
V. Marker-assisted Selection

Early Multi-site Trials

Multilocation trials will be conducted in traditional breeding after achieving homozygozity, which occurs after seven to eight generations of selfing. The repeatability of cultivar performance

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across years and sites in standard multilocation testing is unsatisfactory because varieties bred in one region are largely suited to that location, and when these lines are used in multilocation trials, their performance tends to be poor.This is mostly due to changes in environmental conditions, insect and disease concerns, and soil physical, chemical, and microbiological characteristics across different locales. The cumulative effect of all of these factors results in a decrease in production, further decreasing varietal adaptation across multiple sites.

The early multilocation efforts aimed to stabilise yield but not necessarily improving yield potential. This strategy proposes producing segregating generations in multiple sites, allowing breeders to pick stable genotypes without the need for genetic testing. After 7-8 years of selection in a single area, additional multilocation trials can be performed, saving time.

Flowering Regulation

The number of generations that can be grown in a year is determined by crop growth duration. Every generation commences with the propagating of seeds gained from the generation prior to seed gathering for the next generation. If this may be reduced, More generations can be developed in a year by achieving early blooming and seed set. Growth regulators cause faster blooming in okra, permitting breeders to carry out crosses and collect seeds early. Growing parents under monitored conditions, along with early flowering and seed set, can help to boost the number of generations per year in okra.

Seed soaking in 100 ppm cycocel followed by foliar spray of same regulators resulted in a significant difference in the number of days to 50% blooming, which took 38 days, whereas control and water soaking of seeds delayed it (48 days). (Arora and Dhankar 1992).

Triacontanol spraying induced earlier flowering on the third node in Parbhani Kranti and Arka Anamika, with 50% of plants blooming in 39 days in Parbhani Kranti and 42 days in Arka Anamika (Acharya 2004). Spraying NAA at 50 ppm at 20 DAS resulted in 31 days earlier blooming in the okra cultivar Utkal Gaurav (Sanodiya *et al*. 2017).

Double Haploids

It is commonly recognised that traditional breeding takes time, particularly methods which emphasise selection in segregating generations, such as pedigree and bulk breeding. It takes 7 generations for these methods to produce 99.22% homozygous lines. Furthermore, it is time-consuming and needs manual self-pollination each year. The evolution of haploid plants using pollen/ovule culture, followed by chromosome doubling, enables for the creation of 100% homozygous individuals in a shorter period.

Because they possess just a single pair of alleles at each locus, haploids are the source of homozygosity. By doubling the chromosomes, it is feasible to generate homozygous and uniform lines. This strategy is extremely useful for investigating the impact of recessive genes. This method saves more time than the traditional method. In the early 1980s, the availability and development of in vitro techniques, particularly anther culture for the induction of androgenesis, boosted interest in the creation of haploids for crop improvement (Bajaj, 1983; Hu, 1985).

Heterosis breeding

The first generation (F_1) of a cross between two genetically different parents exhibits hybrid vigour. When compared to pedigree breeding, hybrids save a lot of time because they are picked within the F_1 generation. Hybrid vigour has also been used to create hybrids resistant to yellow vein mosaic virus. Hand emasculation and pollination were then used to create hybrids.

Several researchers have reported a wide spectrum of heterosis in okra traits. Hybrid vigour was additionally employed to create hybrids resistant to yellow vein mosaic virus. However, the actual application of heterosis in okra is very limited. Only when it implies an improvement above the best commercial types will heterosis be meaningful. According to Hamon and Charrier (2001), genetic studies of many characteristics in Indian cultivars reveal additivity, sometimes with minor dominance, for blooming period, fruits per plant, plant height, and branches per plant. The overall impression In most circumstances, the ability to combine is dominating. However, some specific combinations for fruit-bearing branches, seeds per fruit, fruit length, and fruit diameter are probably worth considering.

Marker-assisted Selection

The use of molecular markers provide for the confirmation of the existence or absence of a specific locus without waiting for the phenotypic display of a specific trait, thus allowing for the early selection of genotypes. Unfortunately, the use of molecular markers in okra improvement tends to be limited due to the lack of molecular markers; no genetic map or other genetic tools are available. Due to the large number of the chromosome (polyploidy) and bigger genome size, i.e. about 1600 mb (Sastry and Zitter 2014; Mishra *et al*. 2017), no linkage map has been established in okra so far, and reports on marker development are very insufficient and mainly are centred around cultivar characterization (Mishra *et al*. 2017).

Due to the presence of substantial amounts of mucilaginous acidic polysaccharides, with polygalacturonic acid as the primary component in the tissue, no effective procedure for DNA isolation and purification in okra exists (Ahmed *et al*. 2013). The nucleic acids interact with these polysaccharides during cell lysis, and the oxidised form of polyphenols binds to the proteins and nucleic acids, generating a dark gelatinous substance, resulting in a low yield and purity of the recovered DNA. Furthermore, DNA dissolved in polysaccharides inhibits numerous biotechnological operations such as restriction digestion, PCR, and in vitro labelling (Sahu *et al*. 2012).

Patil *et al*. (2018) identified the YVMV-resistant genotypes by amplifying the virus DNA in the plants. They examined 18 okra genotypes employing the two primers that amplify the OYMV DNA in plants for evidence of virus infection, and they were able to distinguish between susceptible and resistant genotypes. According to the outcomes of this study, these primers can be used to detect resistant genotypes in the initial stages of plant growth.

Non-traditional breeding techniques

The quantity of current diversity, breeding systems, and inter- and intra-specific compatibility all affect the efficacy of conventional breeding is. Despite the fact that okra has a large genetic base from its many wild relatives, its utilisation frequently challenging because of barriers to hybridization and polyploidy. The development of pre-breeding lines with biotic stress resistance requires the urgent adoption of unconventional methods of breeding integrating biotechnological tools since the resistance to YVMV is not stable in cultivated species and frequent failures of resistance have been noticed in developed varieties.

A virus disease discovered in 1984 was enation leaf curl. This disease primarily affects the okra crop in the southern states. Among the available cultivated germplasm, no source of resistance to enation leaf curl virus (ELCV) has been found. Some wild species of okra (*Abelmoschus crinitus, A. ficulneus, A. angulosus, and A. manihot)* show stable and reliable sources of ELCV resistance (Singh *et al*. 2007, 2009). However, the transmission of resistance from wild relatives has been limited by sterility issues, and its hard to produce subsequent generations or even carring backcrosses also difficult (Yadav *et al*. 2018). Crosses with *A. ficulneus* as either male or female parent produced no fruit, and crosses with *A. moschatus* produced hybrid inviability (Rajamony *et al*. 2006). In such instances, Nonconventional breeding methods, such as mutation breeding and recombinant DNA technologies, are beneficial and faster than traditional breeding methods.

Tissue culture and genetic transformation

Backcrossing is a well-known traditional breeding strategy for transferring a single or few genes into a genetic background. Backcrossing is commonly used to transfer genes from wild relatives. A backcross plus pedigree technique was employed to transfer YVMV resistance from wild relatives to cultivated okra. Backcrossing has limits because it is dependent on sexual compatibility and can take 10-15 years to generate a new variety due to substantial backcrossing (Pauls 1995). In general, it needs 7 backcrossings to recover 99.22% of the recurrent parent genome. These constraints have fueled the development of more complex technologies, such as plant genetic transformation.

The development of gene transfer technologies has made significant progress, resulting in the creation of a huge number of genetically altered plants. The potential benefits of these transgenic plants include increased yields and improved quality, nutritional values, reduced pesticide and fertiliser use, and better soil and water pollution control (Rekha Rani 2007).

Many studies have used cotyledon, cotyledonary node, cotyledonary axis, hypocotyl, shoot tip, and plumule from the zygotic embryo of okra for callus induction and regeneration utilising various growth regulators (Narendran *et al*. 2013).

The most frequent method of transformation is agrobacterium-mediated gene transfer. Rekha Rani (2007) developed a methodological framework for Agrobacterium-mediated gene transformation in okra. Okra was genetically transformed using Agrobacterium carrying the plasmid pBI121 with a selectable marker gene npt-II that provides resistance to the antibiotic kanamycin.

Fruit borer is a problem in okra that is difficult to control due to the larva's feeding in the pod's interior. Narendran *et al*. (2013) developed an okra tissue culture regeneration procedure that incorporates zygotic embryo explants and Agrobacterium-mediated transformation. They created seven transgenic lines with the cry1Ac gene to acquire resistance against the fruit borer, and feeding on the transformed fruits of these lines resulted in 100% larval mortality, confirming the existence and expression of the transgene in transgenic Bt plants.

Mutation Breeding

Apart from segregation and recombination, mutation is a sudden heritable alteration in an organism's genetic constitution. Gamma rays and ethyl methane sulfonate (EMS) are the most commonly employed mutagens. Mutation breeding is effective when no variation for the desired characteristic exists in the existing germplasm population or when it cannot be used owing to incompatible barriers. In such circumstances, mutagenesis can be used to generate variation for desirable features. Furthermore, selection begins with the first mutagenic generation (M_1), whereas in pedigree breeding, it begins in the third year (F_2), therefore it speeding up the breeding operation.

In terms of population variability, the second generation (M_2) of mutation breeding is comparable to the third generation (F_2) of pedigree breeding. Attempts have been made in okra to increase diversity through mutation procedures. However, only a few economically valuable mutants have been found for cultivation in India, namely Punjab-8 (EMS-8), an induced mutant of Pusa Sawani using EMS (1% ethyl methane sulfonate) treatment. This mutant increased yield by 107%, increased fruit number by 16%, and reduced YVMV disease by 99%. The mutant also has a high level of resistance to the fruit borer. Its infestation was reduced by 46%. MDU-1, an induced mutant of Pusa Sawani developed by Tamil Nadu Agricultural University, Coimbotore in 1978 and Prabhani Tillu, also an induced mutant suitable for processing.

Singh et al. (1998) observed In a gamma radiation and EMS-induced okra population, the largest genotypic and phenotypic coefficients of variation were recorded for number of fruits per plant, yield per plant, and plant height. Mishra *et al*. (2007) reported that when okra was treated with 30 kR, the mean fruit number/plant, fruit length, and fruit yield/plant rose when compared to the control in okra. Dalve et al. (2010) found that increasing the mutagenic dose increased the days for first flower appearance, 50% flowering, and days required for first fruit set. According to Jagajanantham *et al*. (2012), smaller doses of gamma rays boost okra growth and yield characteristics, whereas higher doses of gamma rays increase days to first flower.

Conclusions

Okra is an essential and precious vegetable. In order to meet the future needs of the ever-increasing human population, it is necessary to produce high yielding, pest- and disease-resistant, abiotic stress-tolerant, nutritionally rich varieties at a faster rate.To attain this goal, okra breeding must be speed up or hastened. The potential for increasing okra breeding are examined in this topic. The approaches described will assist breeders in speeding up the okra improvement programme.

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Chapter 17

miRNA : Biogenesis and Applications

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Introduction

MicroRNAs (miRNAs) are a class of small non-coding RNA molecules that play crucial roles in the regulation of gene expression in various organisms. Discovered in the early 1990s, miRNAs have since emerged as important regulators of numerous biological processes, including development, cell differentiation, proliferation, and apoptosis. These tiny RNA molecules are involved in post-transcriptional gene silencing, primarily by binding to the messenger RNA (mRNA) molecules and inhibiting their translation or promoting their degradation.

miRNAs are typically 18-24 nucleotides in length and are transcribed from specific genes in the genome. They are initially synthesized as long primary transcripts known as pri-miRNAs, which undergo a series of enzymatic processing steps to generate mature miRNAs. The primary processing step occurs in the nucleus, where the enzyme Drosha cleaves the pri-miRNA into a shorter hairpin-shaped molecule called the precursor miRNA (pre-miRNA). The pre-miRNA is then exported to the cytoplasm, where it is further processed by an enzyme called Dicer, resulting in the production of the mature miRNA duplex.

One strand of the mature miRNA duplex, known as the guide strand, is preferentially incorporated into a protein complex called the RNA-induced silencing complex (RISC). Within the RISC, the guide strand guides the complex to the target mRNA molecules that possess complementary sequences. By binding to the target mRNA, the miRNA-RISC complex can either inhibit translation by preventing ribosome binding or induce mRNA degradation, thereby regulating the expression of the target gene.

miRNAs have been found to target a wide range of genes, and their dysregulation has been associated with various diseases, including cancer, cardiovascular disorders, neurodegenerative diseases, and immune disorders. Their ability to fine-tune gene expression makes them powerful regulators of cellular processes and key players in maintaining homeostasis in complex biological systems.

In recent years, miRNAs have garnered significant attention in research and biomedical fields due to their potential as diagnostic markers, therapeutic targets, and even as therapeutic agents themselves. Understanding the roles and mechanisms of miRNAs has the potential to revolutionize our understanding of gene regulation and provide new avenues for the development of personalized medicine.

Overall, miRNAs represent a fascinating class of small RNA molecules with immense regulatory potential, and their study continues to uncover novel insights into the intricate mechanisms governing gene expression and cellular function.

Biogenesis of miRNAs

miRNAs are transcribed from DNA by RNA polymerase II or III as primary miRNAs (pri-miRNAs) that are several hundred nucleotides long. These pri-miRNAs are processed by a nuclear RNase III enzyme, Drosha, into precursor miRNAs (pre-miRNAs) that are hairpin structures of approximately 70 nucleotides in length. Pre-miRNAs are then exported to the cytoplasm by Exportin-5 and further processed by another RNase III enzyme, Dicer, into mature miRNAs that are approximately 22 nucleotides in length. The mature miRNAs are then

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incorporated into the RNA-induced silencing complex (RISC), where they bind to target mRNAs and mediate gene silencing through translational repression or mRNA degradation. Following are the key steps of miRNAs biogenesis :

1. Transcription : The process of miRNA biogenesis starts with the transcription of DNA into a primary miRNA (pri-miRNA) by RNA polymerase II in the nucleus.

2. Processing of pri-miRNA : The pri-miRNA is processed by the Drosha-DGCR8 complex into a precursor miRNA (pre-miRNA) which contains a stem-loop structure.

3. Export to cytoplasm : The pre-miRNA is transported to the cytoplasm by exportin-5 and Ran-GTP.

4. Dicing : In the cytoplasm, the pre-miRNA is processed by the Dicer enzyme, which removes the loop and generates a miRNA duplex.

5. Loading onto RISC : The miRNA duplex is then loaded onto the RNA-induced silencing complex (RISC), which consists of Argonaute proteins.

6. Separation of strands : The miRNA duplex is unwound in RISC, and the guide strand (miRNA) is selected to be incorporated into the RISC, while the passenger strand (miRNA*) is degraded.

7. Target binding : The miRNA in RISC then binds to its target mRNA through complementary base pairing, leading to mRNA degradation or translational inhibition.

Function of miRNAs

miRNAs are involved in various biological processes, including cell proliferation, differentiation and apoptosis. They regulate gene expression by binding to the 3' untranslated region (UTR) of target mRNAs, leading to the inhibition of translation or degradation of the mRNA. miRNAs can also target the 5' UTR or coding sequence of mRNA, leading to translational repression. In addition, miRNAs can regulate gene expression by modulating alternative splicing and epigenetic modifications.

miRNA have been implicated in the regulation of various diseases, including cancer, cardiovascular disease and neurological disorders. For example, miR-21 is upregulated in many types of cancer and promotes tumor growth by inhibiting the expression of tumor suppressor genes. Conversely, miR-34a is downregulated in many cancers and act as a tumor suppressor by including cell cycle arrest and apoptosis. In cardiovascular disease, miR-21 promotes vascular smooth muscle cell proliferation and migration, leading to the development of atherosclerosis. In neurological disorders, miRNAs have been shown to regulate synaptic plasticity and neuronal development and dysregulation of miRNA expression has been implicated in the pathogenesis of Alzeimer's disease, Parkinson's disease and schizophrenia.

Applications

Potential application of miRNA in medicine : The dysregulation of miRNA expression has been implicated in various diseases, making miRNAs attractive targets for therapeutic intervention. Several strategies have been developed to modulate miRNA expression, including the use of synthetic miRNA mimics or inhibitors, antagomirs, and small molecules that target miRNA biogenesis or function.

miRNA-based therapies have shown promise in preclinical studies and clinical trials. For example, miravirsen, a synthetic miRNA inhibitor that targets miR-122, has been shown to reduce viral load in patients with hepatitis C virus (HCV) infection. In addition, MRX34, a liposomal formulation of miR-34a mimic, has shown efficacy in preclinical studies and is currently being tested in clinical trials for the treatment of various cancers.

Potential application of miRNA in agriculture : MicroRNAs (miRNAs) are small non-coding RNA molecules that play crucial roles in post-transcriptional gene regulation in plants. They regulate gene expression by binding to complementary sequences in the messenger RNA (mRNA) molecules, thereby causing their degradation or blocking their translation into proteins.

In agriculture, miRNAs have great potential for applications in crop improvement, disease control, and stress tolerance. Here are some potential applications of miRNAs in agriculture :

1. Crop improvement : miRNAs can be used to improve crop yield, quality, and resistance to biotic and abiotic stresses. For instance, miRNAs can be engineered to silence genes responsible for undesirable traits in crops, such as susceptibility to diseases or pests, or low yield. Additionally, miRNAs can be used to enhance traits such as drought tolerance, salt tolerance, and nutrient use efficiency.

2. Disease control : miRNAs can be used to develop disease-resistant crops. For instance, miRNAs can be engineered to target genes in the pathogen or to enhance the expression of genes involved in the plant's defense response. This can lead to enhanced resistance to diseases, such as viral infections or fungal diseases.

3. Stress tolerance : miRNAs can be used to develop crops that can tolerate environmental stresses such as drought, heat, cold, and salinity. For instance, miRNAs can be used to regulate the expression of stress-responsive genes and to enhance the plant's ability to cope with adverse environmental conditions.

4. Herbicide resistance : miRNAs can be used to develop crops that are resistant to herbicides. For instance, miRNAs can be engineered to silence the genes responsible for the herbicide's toxic effect, thereby rendering the plant resistant to the herbicide.

5. Biofuel production : miRNAs can be used to enhance the production of biofuels from crops. For instance, miRNAs can be engineered to enhance the expression of genes involved in the production of biofuels, such as cellulose, lignin, or oil.

Conclusions

Overall, miRNAs have great potential as therapeutic agents for a wide range of diseases. While there are still challenges that need to be addressed, ongoing research and development efforts are likely to lead to the development of new and effective miRNA-based therapeutics in the future. miRNAs have also great potential for applications in agriculture, and their use is expected to revolutionize crop production in the future. However, more research is needed to fully understand the molecular mechanisms underlying miRNA-mediated gene regulation and to optimize their use in agriculture.

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Chapter 18

New Dimensions of Agro-Advisory Services in Relation to Sustainable Agriculture

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Abstract

In the resent year, anomalous weather and climate change have drastically impact on agricultural and allied sectors with greater risk.1t also impact the quality, of absolute production levels of major mitigation crops. Agro- Advisory Services (AAS) have deliberated to the farmers on every day activities to address the issues related to weather & climate change. Daily weather data and weather forecasting are disseminated to the adverse effects through various channels. Agro advisory bulletin (bi-weekly) is prepared and sent to all government bodies, NGO's, Kisan helpline, ETV, All India radio etc. through E-mail and is uploaded on the website working on office day and time. The increasing weather risks affect the livelihoods of farming community and GDP growth of the country. Under these threating and alarming threat condition. It is becoming increasingly important for farmers to proactively manage agriculture & allied sector and the weather and climate risks to agriculture for sustainable livelihood.

Key word : *AAS-Agro advisory services, Climate change, Livelihood, Weather forecast*

Introduction

India has an agriculture-based economy. the SW monsoon season is the main rainfall season for the almost all the stage. The success and failure of crops in the large parts of the country greatly depend on the monsoon rain. We have generally numerous and diverse sources of weather and climate-related risks in farming; limited water resources, drought, land degradation, desertification, hail, flooding, early frosts and many more. It is observed that Efficient mechanism of weather and climate information and advisory services can ensure the appropriate decision-

making of farmers and sustainable management of agricultural risks. Such services can help to evolve sustainable and economically so and agricultural systems, improve production and quality, reduce losses and risks, saving in production costs, increase efficiency in water management and enhanced, labor and energy, conserve natural resources, and minimization of pollution by agricultural chemicals or other agents that contribute to the deterioration of the environment. Thus, the importance of the Agromet Advisory Services have now been emerged as an important tool for risk mitigation and sustainable production.

These Services obviously meet the real-time needs of farmers and contribute to climate change weather-based crop/livestock management strategies and operations dedicated to enhancing crop productivity.

India is a vast country and, it is very tedious to maintain a network of manual meteorological observatories. To fulfill the present and future needs, India Meteorological Department (IMD) has

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established a network of manual observatories, automatic weather stations, automatic rain gauges, ground based radar network. The Agro-Advisory Service (AAS) rendered by IMD, Ministry of Earth Sciences (MoES) is a efficient mechanism to use so relevant meteorological judicious information that farmer make the most efficient use of natural resources, with the aim of improving agricultural production; both in quantity and quality. Advisory services delivered to the farmers on every day, daily weather data and weather forecasting disseminated through the newspapers like; Dainik Bhaskar, Dainik Jagran, Star Samachar, Jan Sandesh, Patrika, Nav Swadesh, Nav Bharat, etc. on phone call for the general public in surrounding area. Agro advisory bulletin/Weather forecast (Twice in a week- Tuesday and Friday) is also prepared and sent to NGO's, FPOs, ATMA, ETV, the office of District agricultural and horticulture officers, all local newspapers published in the district, All India radio, through E-mail. It is also sent to the KMA as well as www.imdagrimet.gov.in. (IMD, Pune).

Agromet Advisory Bulletins

The Agromet Advisory Bulletins are issued at district and block level by District Agro Met Unit (DAMU) and embrace location and crop specific advisories including field crops, horticultural crops, and livestock. The State Level bulletin is jointly prepared by State Meteorological Centre of IMD and

MCs is a composite of district bulletins helping to identify the concerned districts of the state as well as plan to supply appropriate farm inputs such as seeds, irrigation water, fertilizer, pesticides etc. Irrigation Department, Seed Corporation, Transport, and other organizations which provide inputs in agriculture. National Agromet Advisory Bulletins are prepared by National Agromet Advisory Service Centre, Division of Agriculture Meteorology, IMD, Pune, using inputs from various states. This bulletin are very useful to identify stress on various crops for different regions of the country and suitably incorporate advisories.

The bulletins are also used by a large number of other agencies including seed, fertilizer and pesticide industries. At present bulletins are being issued twice in a week i.e. Tuesday and Friday. Agromet advisories help to enhance profits by consistently delivering actionable weather information, analysis and decision support for farming situations such as; to manage pests through the forecast of relative humidity, temperature and wind; manage irrigation through rainfall & temperature forecasts; protect the crop from thermal stress through forecasting of extreme temperature etc. A typical Agromet Advisory Bulletin enables farmers to reap benefits of benevolent weather and minimize or mitigate the impacts of adverse weather are :

District specific weather forecast, in quantitative terms, for next 5 days for weather parameters like; rainfall, cloud, maximum and minimum temperature, wind speed/direction and relative humidity, including forewarning of hazardous weather events (cyclone, hailstorm, heat/cold waves, drought and flood etc.) likely to cause stress on

Standing crop and suggestions to protect the crop from them.

Weather forecast based information on soil moisture status and guidance for application of irrigation, fertilizer and herbicides etc.

Advisories on sowing/planting dates and suitability of intercultural operations covering the entire crop spectrum from pre-sowing to post harvest to guide farmer in their day-to-day cultural operations.

Weather forecast based forewarning system for major pests and diseases of major crops and advises on plant protection measures.

Reducing contribution of the agricultural production system to global warming and environmental degradation through judicious management of land, water and farm inputs, agro-chemicals and fertilizers.

Advisory for livestock on health, shelter, and nutrition.

The support on above is rendered through preparing district specific agro-meteorological advisory bulletins which are tailored to meet the farmers' need and are made relevant to his decision making processes. The suggested advisories generally alter actions in a way that improves outcomes as it contains advice on farm management actions aiming to take advantage of good weather and mitigate the stress on crop/livestock. The bulletins are encoded in a format and language which is easy to understand by the farmer. The agrometeorologists first interpret the immediate past weather and the forecast for the next 5 days and translate it into layman's terms so that the farmers can understand it. They use state-of-art technology such as crop weather models, climatic risk management tools etc. for framing the advisory bulletins. Also, the interaction between the DAMUs and farmers to identify the weather sensitive decisions is

Promoted under the service through a participatory approach. This step fosters a relationship between the IMD, DAMUs, farmers and other stakeholders so that they can identify or diagnose the gaps in weather information and services available from the IMD.

Weather Forecast and Agromet Information

Quantitative district level weather forecast up to 5 days is issued from first June 2008. The product comprises of quantitative forecasts for weather parameters viz. rainfall, maximum and minimum temperatures, wind speed and direction, relative humidity and cloudiness. In addition, the weekly cumulative rainfall forecast is also provided. The products were disseminated to Regional Meteorological Centers and Meteorological Centers of IMD located across the country. These products after value addition using the synoptic interpretation of model output are communicated to DAMUs co-located with SAUs, institutes of ICAR etc. for preparation of district level agro-met advisories bulletin twice a week i.e. Tuesday and Friday. IMD mandate to issue weather forecast for different time scale in advance, it provides an opportunity to efficiently minimize the loss from adverse weather and took the benefit from benevolent weather.

Short Range Weather Forecast

Short range forecast of up to 3 days resolution and now-casting of 3 hours to 6 hours resolution having significance in efficient utilization of agricultural inputs. A network of Doppler Weather Radar (DWR) of IMD efficiently monitors the track of tropical cyclone, cloud movements, rainfall occurrence etc. informs very well in advance and mitigate the risk in agriculture quickly.

Medium Range Weather Forecast

Medium range forecast having a temporal resolution of 3-10 days, this forecast is considered to be most important for in-situ.

Agricultural practices. IMD issues Medium Range Weather Forecast (MRWF) quantitatively for seven weather parameters viz. rainfall, maximum temperature, minimum temperature, wind speed, wind direction, relative humidity, and cloudiness. In addition, the weekly cumulative rainfall forecast is also provided. The accuracy of the forecast is near around 70%. The model has been very successfully capturing the weather related to synoptic system leading to large scale rainfall and such forecast are very important for agricultural operationssuchas irrigation, ploughing, fertilizer application, and chemical spray etc. District-specificmedium-term forecast information and advisory services help to maximize output and prevent crop damage or loss. It also helps farm communities anticipate and plan for irrigation scheduling, pesticide applications, disease, and pest outbreaks and many moreweather relatedagriculture- specific operational practices. Such operations include cultivar selection, their dates of sowing/planting, importantdatesof intercultural operations, dates of harvesting and also performing post-harvest operations.

Extended Range Forecast

Long breaks in critical growth periods of agriculturally important crops lead to substantially reduced yield. Thus, the forecast of this active/break cycle of monsoon, commonly known as the Extended Range Forecasts (ERF) is very useful. The forecasts of precipitation on this intermediate time scale are crucial for the optimization of planting and harvesting. Therefore, is of great importance for agricultural planning (sowing, harvesting etc.) and yield forecasting, which can enable tactical adjustments to the strategic decisions that are made based on the longer- lead seasonal forecasts, and also will help in timely review of the ongoing monsoon conditions for providing outlooks to farming communities.

IMD has been issuing experimental ERF since 2009 using available products from statistical as well as an MME technique based on outputs available from dynamical models from various centers in India and abroad. The MME forecast is being prepared once in a week with the validity for subsequent four weeks. However, model runs are made for 45 days every week. The latest generation coupled models are found to be very useful in providing skillful guidance on extended range forecast in agriculture. The performance of extended range forecasts for the SW monsoon seasons clearly captured the delay/early onset of monsoon over Kerala, active / break spells of monsoon and also the withdrawal of monsoon in the real-time in providing guidance for various applications. On the experimental basis, the MME forecast on meteorological subdivision level up to two weeks are also being used in providing the agromet advisory for the farming community. During the other season, the MME based ERF also provides encouraging results in case of NE monsoon rainfall over the southern peninsula and tropical cyclogenesis over the north Indian Ocean during the post-monsoon season from October to December (OND). In addition, the MME based technique ERF forecast also provides useful guidance pertaining to rainfall associated with Western Disturbances (WD) over northwest India during winter. The ERF for minimum and maximum temperatures during winter and summer seasons are also found to be very useful for mitigating risk.

Long Range Forecast

Long-range forecast (LRF) / Seasonal forecast, based on statistical methods LRF has been issued for the SW monsoon rainfall over India for many years in two stages. Rainfall- induced stress associated with the amount and date of occurrence viz. early, the mid and late deficit in rainfall is predicted by long range forecast. Long range forecast provides lead time for strategic planning in agriculture.

Gramin Krishi Mausam Sewa

India Meteorological Department (IMD) is rendering district level weather based agromet advisory service named as "Gramin Krishi Mausam Sewa" since 2008 in the country to cope up with weather and climatic risks and uncertainties. GKMS is multi-disciplinary and multi-institutional project. It involves all State Agricultural Universities (SAUs), Indian Council for Agriculture Research (ICAR), Krishi Vigyan Kendra (KVKs) Department of Agriculture & Cooperation and Farmers' Welfare, State Department of Agriculture, NGOs, Media Agencies etc. Under GKMS scheme weather- based crop and locale-specific agro-advisories for rural districts are prepared and disseminated to farmers deploying various modes of information dissemination e.g. radio, television, print media, internet, Kisan Call Centers and mobile phones. Presently 1.14 crore farmers in the country receive abridged advisories through short message service (SMS) and Integrated Voice Response System (IVRS) on their mobile phone[7].

The services at its current spatial resolution made significant contribution to reduce risk and improve agricultural productivity farm income, despite local climate variations. It also focuses on environment-friendly integrated solutions that are within the farmers' capabilities. It was observed that there has been a substantial increase in productivity for cereals, oilseeds, and vegetable. A comprehensive study on impact assessment and economic benefits of this service carried out in the year 2010 by the National Council of Applied Economic Research (NCAER) report that the contribution to GDP has estimated Rs. 50,000 crores. Weather forecast and warnings have helped to enhance the livelihood security for farmers and rural community in the project region. Further to improve the relevance of this service at block level with high resolution weather forecast will be utilized to develop the services. As a part of GKMS, it is proposed to establish 660 District Agromet Units (DAMUs) at KVKs at each district will be included in a phased manner. Efforts are being made to atomize the process of farm advisory preparation and dissemination through Kisan portal. Service delivery at block and village level will be established using all the dissemination channels including DD Kisan, Kisan portal.

Weather Risk Management Tools

The emerging weather and climate risk clearly offer new risk management tools and opportunities for agriculture. Identifying the location wise risk to weather, the time period during which risk is prevalent and further quantifying and designing a weather risk management strategy based on an index is more relevant to neutralize the risk in agriculture. Under the GKMS scheme, more focus has been started to be given to using the crop simulation model to decide crop management strategies, for the given weather condition. This will help the farmers and planners in tactical and strategical decisions regarding irrigation scheduling and efficient water management in both irrigated and rainfed agriculture system. For particular districts based on realized forecast for strategic/tactical decision support system were generated in few states; the outcomes of risk management options are useful for taking decisions well in advance for crop as well as for other input management and farm activities during different stages of the crop growing season.

Conclusions

In the present scenario of climate change and uncertainty weather condition. Sustainable and adverse farmers need both weather and climate adversely services for crop production. Agromet Advisory services are the of appropriate and efficient mechanism based technical associated with requirement the agriculture locally-appropriate climate and weather information play a making crucial role on risk management in agriculture. At the district level, AAS is underway to extend up to sub-district/block level with dissemination up to village level to

Fulfil the end user's requirements in the irrigated and rainfed systems pertaining to agricultural and allied sectors. Establishment of 660 DAMUs in each district of India at KVK includes 130 existing AMFUs at agricultural university level till 2019 for the weather forecast. Presently there are 200 DAMU running in 200 districts for increasing Agro advisory services proposed plan of IMD and ICAR. Agro advisory services under DAMU has proven to sustainable worth in dissemination the weather based technical information to the farming community in desired manner.

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Our Conference Memory

About the Chief Editor

Chief Editor

Dr. S.P. Singh, born in Village Jevri, Post Rajbun, District Meerut (U.P.), in 1970 and Graduated in Agriculture with Honors from G.M.V., Rampur Maniharan, Saharanpur (U.P.). He did his Post Graduation in Agricultural Botany, Institute of Advance Studies, Meerut University Campus, Meerut and Doctorate in the same discipline (Ag. Bot.) from C.S.J.M. University, Kanpur. Presently, he is working as Scientist (Plant Breeding) at C.S.A. University of Agriculture and Technology, Zonal Agriculture Research Station, Kalai, Aligarh (U.P.). Dr. Singh is a fellow of SRDA, and member of many other professional Societies, having 21 years of experience in Research and Extension Education Works. He authored many books such as Plant Breeding, Agriculture at a Glance, Hand Book of Agriculture (Hindi), Crop Physiology (Hindi & English), College Botany, Environmental Science & Agroecology, Concepts of Ecology etc. He is well recognized Scientist and having more than 300 publications in reputed National and International Journals. Dr. S.P. Singh is also Editor-in-Chief, Progressive Research-An International Journal & Frontiers in Crop Improvement (both Journals are NAAS recognized), Secretary, Society for Scientific Development in Agriculture & Technology and also Chief Managing Director, Astha Foundation, Meerut, working in the field of Science & Education.

He has been awarded as Best Editor and Writer Award-2006, Young Scientist Award-2007, Dr. M.S. Swaminathan Young Scientist Award-2009, Distinguished Scientist Award-2014, Scientific Initiator Award-2014 from Directorate of Rice Research, Hyderabad, Science Leader Award-2015 From RVSKVV, Gwalior, Outstanding Scientist in Agriculture Award-2016, Outstanding Achievement Award-2016, Excellence in Research Award-2017, Innovative Scientist of the Year Award-2017 Outstanding Scientist in Agriculture Award-2018 Before this International conference, Dr. S.P. Singh has already organized five conference at different corner of country, first conference was National symposium on "Achieving Millennium Development Goal : Problems & Prospects" at Bundelkhand University, Jhansi (UP) during October 25-26, 2009 under the umbrella of SSDAT, Meerut, Dr. Singh has been acted as an Organizing Secretary. The second was National conference on Emerging Problems and Recent Advances in Applied Sciences : Basic to molecular Approaches (EPRAAS-2014) during February 08-09, 2014 at Ch. Charan Singh University, Meerut (UP) again by SSDAT, Meerut in which Dr. S.P. Singh has played his role as an Organizing Chairman. The Third, Conference was Organized by SSDAT, Meerut and Astha Foundation, Meerut at Directorate of Rice Research, Hyderabad on Emerging Challenges and opportunities in Biotic and Abiotic Stress Management (ECOBASM-2014) during December 13-14, 2014. Fourth Conference organized by Astha Foundation, Meerut & SSDAT, Meerut at RVSKVV, Gwalior on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2015). Fifth Conference was jointly organized by SSDAT, Meerut & Astha Foundation, Meerut at PJTSAU, Rajendranagar, Hyderabad, Telangana State on Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS-2016) during December 10-11, 2016. Sixth Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, MPUAT, Udaipur; CSAUAT, Kanpur; UAS, Raichur at MPUAT, Udaipur, Rajasthan on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2017). Seventh Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; IGKV, Raipur; BAU, Sabour; MPKV, Rahuri; RARI, Durgapura, Jaipur; Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2018). Eight Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; IGKV, Raipur; BAU, Sabour; MPKV, Rahuri; UAHS, Shivamogga, Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2019). Ninth Conference organized by SSDAT, Meerut in collaboration with Astha Foundation, Meerut, Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS-2020) at Bangkok, Thailand. Tenth International Web Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; IGKV, Raipur; BAU, Sabour; MPKV, Rahuri; BAU Rachi and UAHS, Shivamogga on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2020). Eleventh International Web Conference organized by SSDAT, Meerut in collaboration with Astha Foundation, Meerut, CSAUAT, Kanpur; IGKV, Raipur; MPKV, Rahuri; BAU Rachi and UAHS, Shivamogga on Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS-2021). Twelth International Web Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; IGKV, Raipur; BAU, Sabour; MPKV, Rahuri; BAU Ranchi and UAHS, Shivamogga on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2021). Thirteen International Conference in Hybrid Mode organized by SSDAT, Meerut in collaboration with Astha Foundation, Meerut, CSAUAT, Kanpur; HPU, Shimla; BAU Ranchi, HFRI, Shimla and HNBGU, Srinagar on Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS-2022). Fourteen International Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; BAU Ranchi; RLBCAU, Jhansi; SKRAU, Bikaner; ICAR-CIFE, Mumbai; AFU, Rampur, Chitwan, Nepal; NPU, Palamu and RK (P.G.) College, Shamli on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2022).

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