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GRISAAS

An Edited Book

Volume-2

Chief Editor : **Dr. S.P. Singh**

Compiled & Edited for

Astha Foundation, Meerut (U.P) INDIA

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Global Research Initiatives for Sustainable Agriculture & Allied Sciences

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Editors

- Dr. Brajendra, Hydrabed
- Dr. B.V. Tamburne, Raichur
- Dr. Mahender Singh, Shimla
- Dr. P.B. Singh, Udaipur
- Dr. K.K. Pramanik, Shimla
- Dr. Hiranmayee Nayak, Bhubaneshwar
- Dr. Rohit Rana, Shamli
- Dr. Harish Pal Bhati, Meerut

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Chief Editor

Dr. S.P. Singh

Department of Genetics & Plant Breeding
CSAUAT-Agriculture Research Station, Kalai, Aligarh (U.P.) India

Editors

Dr. Brajendra : ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana
Dr. B.V. Tamburne : Deptt. of Genetics & Plant Breeding, University of Agricultural Sciences, Raichur, Karnataka
Dr. Mahender Singh : Deptt. of Biosciences, Himachal Pradesh University, Summer Hill, Shimla, H.P.
Dr. K.K. Pramanik : ICAR-Indian Agricultural Research Institute, Regional Station, Shimla, H.P.
Dr. P.B. Singh : Deptt. of Genetics & Plant Breeding, Maharana Pratap University of Agriculture & Technology, Udaipur, Raj.
Dr. Hiranmayee Nayak : Deptt. of Agroforestry, Odisha University of Agricultural Sciences, Bhubaneshwar, Odisha
Dr. Rohit Rana : Deptt. of Entomology, Rashtriya Kishan Post Graduate College, Shamli, U.P.
Dr. Harish Pal Bhati : Deptt. of Botany, Government College (CCS University, Meerut) Jewar, G.B. Nagar, U.P.

Published by :

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ASTHA FOUNDATION
Suman Villa, 85, Phool Bagh Colony, Meerut-250002 (U.P.) India
Mob. : 9450068438, 8273775051
Email : dr.sp.singh24@gmail.com
Website : www.asthafoundation.in

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Astha Foundation
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Mob. : 9450068438, 8273775051
Email : dr.sp.singh24@gmail.com
Website : www.asthafoundation.in

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From Chief Editor's Desk

GRISAAS : An Initiative Towards Sustainable Agriculture & Allied Sciences

S.P. Singh
Sr. Scientist (GPB), ARS, Kalai, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) India
Chief Editor, *GRISAAS Series of Edited Books and Souvenior*
President, *Astha Foundation, Meerut (U.P.) India*
Secretary, *Society for Scientific Development in Agriculture and Technology, Meerut (U.P.) India*
Chief Editor, *Frontiers in Crop Improvement Journal, NAAS Accridated Journal (NAAS Rating **4.67**)*
Editor-in-Chief, *Progressive Research–An International Journal, NAAS Accridated Journal (NAAS Rating **3.78**)*

About GRISAAS

Global research initiatives for sustainable agriculture and allied sciences (GRISAAS), 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 since last six years. The eleven different themes of sessions were planned for the GRISAAS and these themes itself explains the vision of GRISAAS are :

1. Innovative technology for crop improvement, biotechnology and genetic engineering
2. Impact of climate change on biodiversity, food security and IPR issues
3. Precision horticulture for augmenting farmer's income
4. New frontiers in disease and pest management
5. Food processing, value addition and post harvest technology
6. Agroforestry, livelihood and sustainable management practices
7. Cropping system indigenous technical knowledge : Policies and economics of profitable agriculture
8. Integrates approaches in physical, chemical and biological sciences
9. Soil health management and practices : Key factor for crop productivity
10. Animal health, animal husbandry and dairy technology
11. Social sciences, library, information science and humanities

The **first GRISAAS** conference was organized during 12-13th December, 2015 at Rajmata Vijayaraje Scindia Krishi Viswa Vidhyalay, Gwalior (M.P.). It received overwhelming response with the registration of more than **1000** participants. The **second GRISAAS** International Conference was organized during 02-04th December, 2017 at Maharana Pratap University of Agriculture and Technology, Udaipur Rajasthan with the registration of more than **1200** participants. The **third GRISAAS** International Conference was organized during 28-30th October, 2018 at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan with the registration of more than **1000** participants. The **fourth GRISAAS** International Conference was organized during 20-22nd October, 2019 at ICAR-National Academy of Agricultural Research Management (NAARM), Rajendranagar, Hyderabad, Telangana with the registration of more than **1000** participants. During the pandemic era, **fifth GRISAAS** one was organized in online mode on 28-30th December, 2020 from the headquarter of Astha foundation, Meerut, U.P. with the registration of more than **1000** participants. Again to stick with corona guidelines the **sixth GRISAAS** International Conference was scheduled in hybrid mode during

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13-15th December, 2021 at Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan. However, due to COVID new guidelines and restrictions due to OMICRON variant of corona, university showed its inability to host it in physical mode so it was also being organized from the headquarter of Astha foundation, Meerut, U.P. with the registration of more than **1500** participants One thing was common in all the conferences that in all the conferences the registrations from the scientific communities and students crossed the **1000 mark limit** and it **reached to 1500** in online mode. The Seventh GRISAAS International Conference was organized in hybrid mode at the campus of Birsa Agricultural University, Kanke, Ranchi, Jharkhand during 21-23 November, 2022. This time more than **1000** participant with **250 offline** participation in expected including some foreign experts. It shows the linkage and faith of scientific community in the Astha Foundation and SSDAT.

Thus the society is serving the scientific and farming community through sharing a common platform with the publication of literature on recommendations based on the conferences organized and problem solving of the stake holders.

GRISAAS : 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 over-looked 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

Precision Farming in Spice Crops : An Indian Perceptive

J.S. Aswani[1*], Sreekala G.S.[1] and Akhil Krishnan[2]
[1]*Department of Plantation Crops and Spices, College of Agriculture, Vellayani-695522, Kerala Agricultural University*
[2]*Department of Agricultural Extension, College of Agriculture, Vellanikkara-680656, Kerala Agricultural University*
**Email :* aswanijs4@gmail.com

Introduction

Spice sector is one of the foreign exchange earning sectors of horticultural crops. The annual production of spice had a hike from 67.64 lakh tonnes in 2014-15 to 106.79 lakh tonnes in 2020-21 with an annual growth rate 7.9%, with an increase in area from 32.24 lakh hectare to 45.28 lakh hectare. Cumin (14.8%), garlic (14.7%), ginger (7.5%), fennel (6.8%), coriander (6.2%), fenugreek (5.8%), red chilli (4.2%) and turmeric (1.3 %), showed a significant growth rate in production during the above period. Spices are one of the major dollar earning crops contributing 41 per cent of the total export earnings from all horticultural crops and fourth among agricultural commodities. During 2014-15 to 2020-21, the spice export had a tremendous jump from 8.94 lakh tonnes worth Rs. 14900 crores to 16 lakh tonnes valued at Rs. 29535 crores (US$ 3.98 billion). The annual growth rate of export is about 9.8 per cent in terms of volume and 10.5 per cent in terms of value (DASD, 2021). Though the area under spice production had a striking growth, the productivity of the spice crops remains less. In an era where land and natural resources are eroding, the major focus should lie on boosting crop production per unit of land, input, area and time. In other words, we have to increase the input use efficiency through adoption of modern agro techniques in different crops. One such comprehensive technique is precision farming, which not only improves yield and input use efficiency but also protects the environment.

Precision farming

Precision farming is the comprehensive information and technology based farming system where inputs are managed and distributed on a site specific basis for long term benefit. The integration of modern technologies in agricultural practices can improve the productivity and yield in a sustainable manner. It is basically adding the right amount of inputs from right source in right manner at right time in right location (Subash, 2014). The major objectives of precision farming is increasing production efficiency, improving product quality, reducing ecological degradation, more efficient input use, and energy conservation (Nikhil *et al*., 2020).

The precision agriculture cycle consists of three stages. The initial step involves field level data collection by measurement of crop and soil factors that vary geographically as well as field level and conversion of these soil and crop parameters into map form. Based on this data, interpretation and mapping of spatially variable rate for crop input applications is done in second stage. In the final stage, input applications are made based on spatially variable rate maps (Comparetti, 2011).

Tools and techniques in precision farming

Multiple technologies are combined in precision farming. These combinations are all related to one another and are in charge of adoption. (Solia *et al*., 2015). The same are discussed under:

(a) Remote sensing : Remote sensing is a method

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for gathering data on an object without coming into contact with it directly. It provides continuously gathered data about agricultural crops and tracks spatial variability over time at high resolution. (Solia *et al*., 2015).

(b) Geographic information system (GIS) : A geographic information system (GIS) is a computer-based management system used to compute, store, analyse, and display spatial data in a map-like style. It is made up of computers, hardware, software, and practices intended to offer the means of manipulating and displaying spatial data. A GIS can compile, statistically analyze, and present a variety of spatial data types. It serves as a key to unlocking the value of variability-related information.

(c) Global Positioning System (GPS) : Global Positioning System (GPS) is a satellite based navigation system used to find exact location, assess spatial variability and site specific application of inputs.

(d) Variable rate technology : Variable rate application is a method of applying varying rates of inputs in appropriate zones throughout a field. The practice of whole field application of chemicals can be replaced by site specific treatment.

(e) Variable rate applicator (VRA) : Variable rate applicators are farm equipment which precisely control rate of application inputs that can be varied. This equipment works either based on maps or through sensors.

(f) Wireless sensor network (WSN) : Wireless Sensor Network (WSN) is an arrangement of sensors that can be used to monitor various physical phenomena such as soil moisture, water content, soil temperature, soil nutrients, environmental parameters, presence of pests among different crop types and appropriate remedial measures that can be undertaken in a timely manner so as to improve quality produce.

(g) Grid soil sampling : Grid soil sampling uses the same principles of soil sampling but increases the intensity of sampling. Soil samples are collected from systematic grids which also have location information that allows the data to be mapped.

(h) Yield monitoring : Crop yield measuring devices are installed in harvesting equipment. The yield data from the monitor is recorded and stored at regular interval along with positional data revised from the GIS unit. GIS software takes the yield data and produce yield map (Solia *et al*., 2015).

(i) Yield mapping : Mapping of yield and correlation of that map with the spatial and temporal variability of different agronomic parameters helps in development of next season crop management strategy (Solia *et al*., 2015).

Application of precision farming under Indian conditions

In Indian aspects, precision farming can be defined as an accurate application of agricultural inputs for crop growth considering relevant factors like soil, weather and crop management practices. In case of spice crops, precision farming can be applied under both open and controlled conditions in the management of following aspects (Subash, 2014) :

1. Good quality planting materials
2. Precise space utilization
3. Water management
4. Fertigation and nutrient management
5. Surface covered cultivation
6. Controlled environment structures

1. Good quality planting materials : Availability of good quality planting material is the most important elements of successful plant production. Majority of the spice crops are vegetatively propagated and a large amount of products are wasted as planting materials. In order to produce high quality, virus free, disease and insect pest resistant planting material in large quantities in a shorter amount of time, various modern propagation methods have been developed for spice crops. (Thapa *et al*., 2017).

Traditionally black pepper is propagated from cuttings obtained from runner shoots with 2-3 nodes. Rapid multiplication method developed in Sri Lanka was modified and adopted in India have resulted in high multiplication ratio (1:40), well developed root system, high field establishment, vigorous growth and better root system. IISR has developed a simple, efficient and cheap method of pepper propagation from single nodes of runner shoots called trench method. Serpentine layering is another method of propagation in which 60 cuttings can be obtained from a mother plant in an year. Plug tray nursery technique involves initial multiplication of black pepper runners in modified serpentine method in soilless nursery media (coir pith and vermicompost in ratio 75:25). Single nodes obtained from this method are planted in plug trays with soilless nursery media supplemented with *Trichoderma* and maintained under humidity controlled green house (27 ± 2^oC) with intermittent mist (IISR, 2015). Column method is a novel method to

Table-1 : Standardized protocols for micropropagation in few spice crops.

Crop	Explants	References
Piper nigrum	Shoot tip and nodal segments for clonal propagation	Dipali and Wankhade *et al.* (2014)
	Stem and leaf tissues for plant regeneration shoot tips for in vitro conservation	Sajc *et al.* (2000)
Elettaria cardamomum	Rhizome bits with vegetative buds	Ravindran *et al.* (2005)
Zingiber officinale	vegetative buds, immature inflorescences and rhizome bits	Abbas *et al.* (2011)
Curcuma longa	vegetative buds and rhizome explants	Shahinozzaman *et al.* (2013)
Amomum subulatum	Vegetative buds and rhizome bits with buds	Pradhan *et al.* (2014)

Table-2 : Recommendation of water through drip irrigation system and fertigation rate in different spice crops.

Crop	Recommendations	References
Black pepper	7 L water per day from Oct to Mar	IISR-AICRP (2020)
	8 litres per day per vine and 50% RDF as liquid fertilizer - 19:19:19 mixture) in 3 equal splits at weekly intervals during June, September and February	IISR-AICRP (2020)
	50% RDF + 8 L drip irrigation	
	Fertigation schedules for three black pepper varieties IISR Thevam, IISR Girimunda and IISR Shakthi were standardized. Maximum yield was recorded in the fertigation treatment with 50% NPK in 24 splits	KAU (2016) IISR (2021)
Bush pepper	8 litres of water per day during Oct - May	KAU (2016)
Cardamom	4 litres per clump per day through drip from January to August in low rainfall tracts	IISR-AICRP (2020)
	9 litres per clump per day along with 100% recommended dose of fertilizers in other areas	IISR-AICRP (2020)
Turmeric	80% pan evaporation (once in a day for 45 minutes) with a total quantity of 538.40 ha mm	IISR-AICRP (2020)
	Application of 100% RDF with urea and potash as straight fertilizers and P as water soluble fertilizer weekly for turmeric growing areas of Tamil Nadu.	IISR-AICRP (2020)
	Fertigation with 150:60:108 kg of NPK/ha and is applied throughout the cropping period once in three days. 75 % of the recommended dose of phosphorous is applied as basal dose. Water soluble fertilizers like 19:19:19, Mono ammonium phosphate (12:61:0), Multi K (13:0:45) and urea are used.	TNAU (2020)
Turmeric (Sugandham)	9 equal splits of 50 % N and K at 15 days interval, starting from cessation of monsoon	Savani *et al.* (2012)
Chili	25% basal + 75% RDF as Fertigation	KAU (2019)
	RDF - 120:64:64 NPK kg /ha Fertigation frequency twice in a week	PFDC (2017)
Clove	8 litres per day per plant during summer months	IISR-AICRP (2020)
Fennel	0.8% IW/CPE ratio on alternate days with paired row planting	TNAU, 2020
	80% of actual evaporation (0.8 IW/CPE ratio) at an interval of 2-3 days with 75% RDF through soluble fertilizers at different growth stages (20, 40, 60, 80 and 100 DAS)	IISR-AICRP (2020)
Cumin	60% of actual evaporation (0.6 IW/CPE ratio) at an interval of 4 days + 80% RDF through soluble fertilizers at different growth stages (10, 20, 40, 50, 70 and 80 DAS)	IISR-AICRP (2020)
Fenugreek	0.6% IW/CPE ratio on alternative days with paired row planting	TNAU, 2020
Coriander	80% of actual evaporation (0.8 IW/CPE ratio) at an interval of 2-3 days + 100% RDF through soluble fertilizers at different growth stages (20, 40, 60 and 80 DAS)	IISR-AICRP (2020)
Big onion	Fertigation of 60:60:30kg of NPK/ha is applied throughout the cropping period as splits once in every 3 days.	TNAU, 2020
Onion (Pilipatti)	9 equal splits of N and K at 10 days interval, starting from 30 days after plating	Savani *et al.* (2012)

Table-3 : Site specific nutrient management in coconut based cropping system of black pepper and nutmeg.

	Black pepper	Nutmeg
Acid soil amelioration	pH < 6.0: 500 g dolomite + 500 g gypsum (May-June)	pH < 6.0 : 1 kg dolomite + 1 kg gypsum (May-June)
	pH > 6.0 : alternate years	pH > 6.0: alternate years
Nutrient management	NPK based on test values	NPK based on test values
	Micronutrient mix 5g/L water twice (flowering and berry development)	Micronutrient mix 5g/L water twice (flowering and berry development)
Health management	Enrich FYM - FYM : *Tricoderma asperellum or Pochonia chlamydosporia* (9:1) at 5-10 kg/vine at onset of monsooon	Enrich FYM - FYM : *Tricoderma asperellum or Pochonia chlamydosporia* (9:1) at 20-25 kg/tree at onset of monsoon
Yield increment %	36.6%	22%

Table-4 : Mulching recommendations for spice crops.

Crop	Recommendations	References
Ginger	Dry leaves at 5t/ha	Sengupta *et al.* (2009)
	Paddy straw: 5 cm thick	Thankamani *et al.* (2016)
	Beds are mulched thickly with green leaves @ 15 t ha-1 immediately after planting and repeated with green leaves twice @ 7.5 t ha-1 first 44-60 days and second 90-120 days after planting.	KAU, 2016
Mango ginger	Mulching with green leaves @ 15 t ha-1 immediately after planting and repeated after 50 days with the same quantity of green leaves.	KAU, 2016
Turmeric	Dry grass: 5-10 cm thick	Chitra *et al.* (2020)
	Straw mulch (6t/ha) and irrigation scheduling at 1.2 IW/CPE	Kaur and Brar (2016)
	Mulched with green leaves @ 15 t ha-1 immediately after planting and repeated after 50 days with the same quantity of green leaves.	KAU, 2016

intensify pepper planting materials using vertical columns with soilless media. With this technique, 150 single node cuttings, 10–15 laterals, and 10 top shoots can be developed in four to five months (IISR, 2015).

Rapid multiplication of ginger through single bud rhizome technology has been standardized at ICAR-Indian Institute of Spices Research, Kozhikode, Kerala. In this technique, single bud (about 5 g) has been used to raise transplants in portrays (98 wells) with nursery medium containing partially decomposed coir pith and vermicompost (75:25), enriched with PGPR/Trichoderma 10g/kg of mixture and maintained under shade net house. The transplants become ready for planting after 30-40 days. The major advantage of this method is reduction in quantity of seed rhizomes, reduced cost of seeds, good establishment (98-100%), early rhizome development and an on par yield as compared to conventional method (Prashath *et al.*, 2016). Shylaja *et al*. (2018) conducted a study to standardize planting material and fertigation schedule in ginger for high tech polyhouse. The plants were evaluated in the potting mixture sand, soil and cowdung (1:1:1) and cocopeat media. Single bud transplants and microrhizomes performed better than conventional 20 g seed rhizome bit in both potting mixture and coirpith medium. Of the three fertigation schedules tried in potting mixture, the lowest fertigation dose of 75:50:50 NPK kg/ha recorded highest values for morphological and yield characters. In turmeric a transplanting technique using single bud sprouts (about 5g) has been standardized at Horticulture College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. Single buds are obtained from healthy rhizomes treated with carbendazim (2g/L) and quinalphos (1.5 ml/L) and covered lightly with cocopeat followed by a humic acid spray (0.5%). Later single buds were transferred into the pro-tray filled with cocopeat enriched with *Pseudomonas fluorescens* (1g per 100 gram cocopeat) and covered with polyethene sheets for seven days. After sprouting, remove polythene sheets, keep in 50% shade, spray humic acid (0.5%) after the emergence of leaf and seedlings will be ready for transplanting after 30-35 days (IISR-AICRP, 2020). *In vitro* induction of microrhizomes in ginger, turmeric and Kaempferia is reported by many workers (Bhat *et al.*, 1994; Nirmal Babu, 1997; Sunitibala *et al*., 2001; Nirmal Babu *et al*, 2003). Microrhizomes are *in-vitro* formed rhizomes having 2 to 4 nodes and 1 to 6 buds, are genetically more stable as compared to micro propagated plants. Microrhizome derived plants produced more tillers, smaller plant height, high recovery rate, lesser yield with no diseases (Prasath *et al*., 2017).

Micropropagation

Micropropagation is the production of plant from very small plant parts, tissues or cells grown aseptically under controlled environment (Subash, 2014). Use of micro propagated plants are practiced in precision agriculture.

Precise space utilization : Malabar type varieties of cardamom are highly suitable for high density planting in cardamom. About 3,025 plants can be accommodated in 1 hectare land with spacing 1.8 x1.8 m (3025 plants/ha). IISR released two Malabar type varieties CCS–1 and Mudigere–1 which are suitable for high density planting. In tree spice crops like, clove, nutmeg, garcinia, allspice, etc., dwarf and compact canopy is ideal for high density planting (HDP), better intercultural operations, easy harvest and better intercropping systems. So identification of dwarf rootstocks and standardization of grafting techniques are one of the major research objectives. Short-statured variant (dwarf) of clove (*Syzygium aromaticum*) was grafted successful on ordinary clove rootstock using approach grafting method and the graft union was obtained in 6–8 months with 64% success and 100% field establishment. Dwarf clove plants will facilitate easy harvesting as well as for high density planting (Mathew *et al*., 2006). Garcinia and nutmeg grafts using orthotropic shoots as scion can be used for the HDP (IISR-AICRP, 2015). High density planting of curry leaf at 0.6 x 0.9 m recorded higher quality characters like essential oil, crude protein, iron and calcium content (Jagadeeshkanth *et al*., 2017).

Water management

Microirrigation : As water availability for irrigation is declining with progress of time due to stiff competition from domestic, industries and other sectors, its efficient utilization is becoming more and more important. In the context of precision farming, drip and sprinkler methods of irrigation are considered as most efficient methods (PFDC, 2017).

Fertigation and nutrient management

Fertigation : Fertigation is the process of dissolving fertilizers at appropriate concentrations in water and applying it through irrigation water by micro irrigation systems. Nutrients and water are applied in required quantity at correct time in the root zones to maximize their absorption. It can increase the fertilizer use up to 90 percent and saves water upto 40 - 60 percent (Kumar and Singh, 2002). Fifty percent recommended dose of fertilizer along with 8 L of water can be applied along drip irrigation (KAU, 2016). Fertigation requirement of some spice crops has been mentioned in table-2.

Diagnosis and recommendation integrated system (DRIS)

Diagnosis and recommendation integrated system (DRIS) uses nutrient ratios to interpret tissue analysis rather than concentrations. DRIS norms were standardized for soil and leaf nutrient concentration in black pepper and cardamom.

Nutritional diagnosis in black pepper using DRIS

The leaf analysis and yield data of pepper vines from major pepper growing areas of Kerala and Karnataka were used for a study consisting of population of 578 vines. Nutritional norms were worked out. The optimum nutrient arrived from this population is 2.2, 0.11, 2.02, 2.67, 0.22 and 0.21 % respectively for N, P, K, Ca, Mg and S. Regarding micronutrients the status were 329, 467, 29 ppm for Fe, Mn and Zn, respectively (Srinivasan *et al*., 2012).

Site specific nutrient management

Site specific nutrient management (SSNM) is an approach of supplying plants with nutrients to optimally match their inherent spatial and temporal needs for supplemental nutrients. The SSNM provide an approach for need based 'feeding' of crops with nutrients.

The SSNM approach aims at increasing farmers' profit by achieving the goal of maximum economic yield (Verma *et al*., 2020). Assessment of soil and crop variability, managing the variability and its evaluation are three basic steps in site specific nutrient management. The available technologies enable us in understanding the variability and by giving site specific agronomic recommendations we can manage the variability that make precision farming viable and final evaluation must be an integral part of any precision farming system.

Pusphpalatha and Bidari (2020) conducted a survey to study the leaf nutrient norms using Diagnosis and Recommendation Integrated System (DRIS) for Byadgi chilli crop in three districts of North Karnataka. The identification of nutrients imbalance through

DRIS indices indicated potassium as the most yield limiting followed by sulphur, magnesium and phosphorus. The optimum concentrations of N, P, K, Ca, Mg, S, Fe and Zn in index leaf ranged from -2.74 to 3.14, 0.54 to0.71, 3.86 to 4.74, 2.27 to 2.94, 0.93 to 1.19, 0.44 to 0.51 per cent, 75.30 to 92.37 and 28.28 to 30.15 mg/kg respectively.

Hakkim (2014) reported that site specific drip fertigation with daily drip irrigation recorded highest number of fruits, fruit length and total green fruit yield in chilli followed by the treatment site specific drip fertigation in the low fertility areas. However, no significant difference was observed between site specific drip fertigation and recommended dose drip fertigation along with daily drip irrigation for high fertility area.

Micronutrient mix

About 40-55% of Indian soils are moderately deficient in micronutrients like zinc, while 25-30% is deficient in boron. IISR have developed crop/soil specific *i.e.,* ginger and turmeric (for soils with pH below and above 7), black pepper and cardamom micro nutrient mixtures for foliar application. The novelty of this technology augments the uptake of essential nutrient by the plants. These micronutrient mixtures can guarantee 15-25% increase in yield and quality.

Crop specific micronutrient mixture application @ 5 g/L as foliar spray twice a year during April-May and August-September is recommended for black pepper. Crop-specific micronutrient mixture @ 5g/L water applied as foliar spray at 60 and 90 days after planting is recommended in ginger and turmeric (IISR-AICRP, 2020).

Surface covered cultivation

Mulching : Mulching is age old practice of covering the soil surface with crop residues or weed biomass or pebbles or plastic. Advantages of adoption of mulching technologies are moderation of soil temperature, increases soil air CO_2 content, minimizes evaporation and weed growth. Mulching with coconut husk along with drip irrigation (100% PE) was found to be effective in drought mitigation in nutmeg (KAU, 2019). In black pepper, mulching of plant bases with coir pith or dry leaves, shading of young plants, moisture conservation tillage and spraying of 1 percent lime can form better adaptation strategies against impact of climate change (KAU, 2019). Sandra and Sreekala (2019) suggested the use of mango leaves at 30t/ha in transplanted ginger for increasing the growth as well as yield parameters.

Plastic mulches are very effective for evaporation controls provided cost is not limiting factors. Both, black and transparent films are generally used for mulching. Advancement in plastic chemistry has resulted in development of films with optical properties that are ideal for a specific crop in a given location. Thankamani *et al*. (2016) suggested the use of ash coloured mulches on controlling weed growth and increasing yield in ginger. Narayan *et al*. (2017) found that double coated black polyethene mulches (30 micron) was effective in conserving soil moisture and reducing soil density in chilli. This treatment significantly increased the number of fruits, fruit length, width and yield. In cardamom, if the sowing is done extremely late in the season (November or December), nursery beds are covered with polythene sheets shortly after sowing to improve seed germination (IISR-AICRP, 2020).

Soil solarization : It is method of heating the soil by covering it with thin transparent polyethylene sheets during hot period to control soil borne diseases. This technology is mostly suitable for preparing healthy nurseries of vegetable, flower *etc*. It controls fungal as well as nematode population causing diseases at nursery stage (Sharma and Bharadwaj, 2017). Thirty days soil solarization along with the application of neem cake and *Trichoderma* effectively reduced the number of weeds and increased seed yield and productivity in cumin (Meena *et al*., 2018). For controlling bacterial wilt of ginger under organic system of cultivation, soil solarization along with the biocontrol agent, *Bacillus licheniformis* (GAP107 MTCC12725) launched as Bacillich is recommended (IISR-AICRP, 2020).

Controlled environment structures

Green houses are framed structures covered with a transparent or translucent material which provide protection for crop and create environment for growing crops even either during off or pre or postponement of season. The green houses are generally of three types *ie*., high cost green houses with full automation, medium cost green houses with partial automation and low-cost poly houses or naturally ventilated poly houses (NVPH).

Though, high cost green houses are ideally relating to precision farming, yet the scope of NVPH is more in India due to fragmented land holding, poor financial status of farmers, inadequate marketing linkages *etc*. Most popularly adopted structure are green house, polyhouses, tunnels *etc.* (Solia *et al*., 2015).

Direct sowing of seed spices shows low germination rate and low vigour, this permit the weeds to proliferate faster in the initial 30 days, which creates tough plant weed competition and increase labour cost. In nurseries, seedlings of crops *viz*., fennel, dill, ajwain and celery were raised in soilless media (*i.e.,* cocopeat) in plastic beds and also in plug trays and 50-60 days old seedlings were directly transplanted in the fields. Both the systems of nursery raising showed 95-100% success rate in seedling establishment except in ajwain. Similarly, seed spices being grown in arid and semi-arid areas, *rabi* crop faces tremendous pressure of water management. The best combination of the mulching practice is with plug tray nursery raised seedling and drip irrigation for better resource management.

The main problem in the cultivation of seed spices is their susceptibility to frost and cold damage. The umbel stalks are very tender and they hardly survive the cold breeze causing cold injury and death of the flower buds resulting in heavy yield losses. Low cost technologies like raising of plastic walls (150-200 mico meter) of 1-1.5 m height depending upon crop height from the field surface in the northern direction efficiently blocks the flow of cold waves and thus reduce the loss caused by frost significantly (Singh and Singh, 2014).

Transparent plastic covered temporary walk-in-tunnels is also suitable and effective for seed spice cultivation up to a limited extent. Plastic sheet of 150-200 ìm thickness is laid in a semi-circle shape. The height of these walk-in-tunnels is 7 to 9 feet at the center. This type of structure provides protection not only against frost but against unseasonal rains and hailstorms. Since plastic is used, the internal temperature rises and results in vernalization, as it induces early flowering compared to normal open field crop. A crop advancement of 20-25 days was observed for flowering as well as maturity. Combination of plastic covered high tunnels and plastic walls can be used for protected cultivation of seed spices. Insect proof net cover should be UV stabilized nylon net of 40 mesh size.

Seed spices, like coriander and fenugreek are grown during rabi for the purpose of green leaves. During the peak summer months (May to July) the availability of coriander leaves is highly decreased and there is a sharp rise the price. Shade net covered walk-in tunnel is an intervention found to be most suitable for the farmers of arid and semi-arid regions of the country where the summer temperature goes beyond 45°C coupled with hot waves. Mostly 50-60% shading intensity shade net covered walk-in-tunnel can be coupled with low pressure drip irrigation system to obtain good quality coriander leaves (Singh and Singh, 2014). For off season leafy coriander, coriander variety CS 11 is recommended to plant during March-April under 50% agro-shade net and higher yield (4824 kg ha^{-1} with a yield increase of 25% over control) of physiologically matured leaf at 45 days after sowing is recorded (IISR-AICRP, 2020). In order to grow high-quality, nematode- and pesticide-free ginger rhizomes in mild-winter greenhouses, Hayden *et al.* (2004) in Arizona also experimented with soilless aeroponic gardening. The special aeroponic growth systems included a “rhizome compartment,” which was elevated above an aeroponic spray chamber and isolated from the spray chamber. On perlite medium, plants that absorbed bottom heat displayed quicker growth and maturation.

Precision Farming in turmeric cultivation at Coimbatore district, Tamil Nadu

Turmeric field was ploughed four times and farmyard manure was applied at the rate of 25 tonnes per ha and 300 kg of DAP and 150 kg of potash as a basal dose. The field was irrigated using drip irrigation. Turmeric was intercropped with coriander and chilli and red gram as a border crop. Fungicide like thiodan and dithane Z78 at 2ml /lit of water on 20 days after sowing for the control of leaf spots. Spraying of malathion at 2ml/lit of water to turmeric on 40th and 70th day after sowing was effective in controlling shoot borer pests. Drenching the soil with ridomil gold fungicide at 2ml /L can control rhizome rot in turmeric on 50th day after sowing. The expenditure was Rs. 3,35,400 and got high profit of Rs. 9,66,000 per hectare from turmeric, onion, chillies, coriander and red gram (TNAU, 2013).

Challenges and future prospects

High initial and operational costs, lack of awareness and training, complexity and limitation of technology usage, rigidity to adopt/change technology and fragmented land holdings are some of the factors which brings back farmers in adopting precision techniques (Subash, 2014).

Various organizations like National Committee on Precision Agriculture and Horticulture (NCPAH), Precision Farming Development Centres (PFDCs), Indian Institutes of Spice Research, Indian Spice Research Organization (ISRO), M S Swaminathan

Research Foundation, CIAE, Bhopal, *etc*. are promoting precision farming in spices. More agriculture research institutes with greater reach working on eco regional basis, crop specific initiatives for fragmented lands and proper marketing may bring these technologies to the farmers' hands.

Soil health card scheme, Prime Minister Krishi Sinchayee Yojana (PMKSY), Mission for Integrated Development of Horticultue (MIDH), Rashtriya Krishi Vikas Yojana (RKVY), National Horticultural Mission (NHM) etc., are some of the government schemes which helps the farmers in adopting these advanced crop production techniques. ICAR-IISR has developed and launched mobile apps for the benefit of anyone who is interested in black pepper, turmeric, ginger and cardamom. It is a simple, user-friendly application providing authentic and scientific information on cultivation of spices in English and Hindi.

Conclusions

In India, farmers need a comprehensive system like precision farming for combating the diminishing natural resources, climatic vagaries, declining productivity *etc*. As compared to the Western Countries the development and adoption of precision farming in India is a slow process. Precision farming is a direction rather than a destination. Tremendous research works and adaption strategies are needed in this direction to reach our goal from "Land of Spices" to "Leader of spices".

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Chapter 2

Sustainable Agriculture

Bal Veer Singh[1*], Y.K. Singh[1] and S.P. Singh[2]
[1]*Department of Agronomy, C.S.A. University of Agriculture and Technology, Kanpur, U.P.*
[2]*CSAUAT-Agriculture Research Station, Kalai, Aligarh, U.P.*
**Corresponding Author Email : bvs955rajpoot@gmail.com*

Introduction

Since the beginning of time, farming has been a significant economic activity for humans. People's fundamental needs are met by agriculture, hence in the past there has been a lot of attention on commercialising farm output at this level. Through the use of high yielding seed types, chemical fertilisers, pesticides, irrigation, and automation, an attempt has been made to commercialise agriculture. These ingredients were added without taking into consideration any potential negative consequences. The only goal of agricultural organizers is to enhance productivity via the intense and indiscriminate use of pesticides and agrochemicals, despite the fact that, although commercial agriculture improves yield, it also harms the environment and widens social inequalities. Traditional farming uses locally accessible seeds, natural fertilisers, and traditional agricultural tools to provide a very low yield while preserving the environment's balance. As with commercial agriculture, traditional agriculture does not meet the expanding human demand for food. Additionally, traditional agriculture has problems. The moment has come to consider what kind of agricultural system we will require—one that produces enough food to sustain our expanding population without causing any pollution. Recent years have been an increase in the interest of mental, agricultural, and social scientists in finding an alternate strategy for preserving the resources supporting human existence due to the falling trend in carrying capacity of land and other natural resources. The indiscriminate use of pesticides, excessive and incorrect irrigation, and faulty land and water use planning are the major causes of deterioration in the ecosystems that sustain life, particularly in soil and water. The creation of culture is impacted by ecological deterioration in order to maintain its development for future generations. Waterlogging, erosion, salinity and alkalinity, insect and disease issues, and salinity and alkalinity are the main ecological issues influencing agriculture's sustainability. In addition, pests and diseases have evolved a tolerance to insecticides, rendering many previously used treatments useless. Since 235 million tonnes of food would be needed by the year 2000 A.D. to maintain self-sufficiency, it is crucial to find an environmentally friendly strategy for developing and popularising ecology-based low-cost input and financially sustainable foundation. The current introductory chapter illustrates the elements and characteristics of sustainable agriculture in this setting (SA)

Definition

The most popular and often used term today—sustainability—suggests the optimum path for global progress. The term has already been overused and even abused, comprehended by few but flaunted by many. Defining Harwood (1988) from the UK "An agriculture that may continue to develop endlessly toward better human usefulness, more effective resource use, and a balance with the environment that is beneficial to people and the majority of other species is known as sustainable agriculture.

According to the FAO (2016), sustainable agriculture "fulfils food security, environmental

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protection, and economic and social demands in rural regions." Due to the fact that this activity includes both human actions, such as farm management and agricultural policies, as well as several independent variables, such as climatic conditions, topography, soil type, animal gas emissions, etc. [Cymerman 1994; Kiebasa *et al*. 2016], this effort is difficult. Sustainable agriculture aims to conserve and maintain natural resources. Some of these may be severely harmed or polluted, badly damaged, or depleted, such as soil nutrients (groundwater or water courses). Later this century, several natural resources like phosphorous are anticipated to become depleted. So, in order to preserve and safeguard resources, more sustainable agriculture techniques are developing [Cordell and White 2011].

Because the production of goods and raw materials is a continual process, such as in agriculture, sustainability is more important in these contexts. Throughout our lifetimes, it demands resources, inputs, information, skills, and markets. When the natural resource base on which the production activity relies (in this instance primarily land, water, and air) is not damaged or degraded in any way that may jeopardise production and advancement at any point in the future, sustainable production is conceivable.

Dimensions

The distinguished agricultural scientist Dr. M.S. Swaminathan highlighted fourteen key aspects of SA, including its social, economic, technical, political, and environmental aspects.

These measurements are :

I. The term "technological appropriability" describes how well agricultural technology —whether it be a seed, fertiliser, pesticide, or enhanced machinery—fits into the end users' social and physical environment.

II. Economic viability: describes a farmer's ability, given his financial situation and position, to implement the technology into his farm.

III. Economic viability is a term used to describe the returns on investments when each dollar counts.

IV. Environmental soundness is the question of whether a technology improves the environment or at the very least does not damage the agro-ecological conditions that already exist.

V. Temporal stability: This term describes whether the advantages of the technology endure through time.

VI. Resource-use efficiency measures how well technology can use inputs to produce useful, fruitful, and environmentally friendly outputs.

VII. The degree to which a technique may be adapted to the farmers' current local circumstances is referred to as "local adaptability."

VIII. Social acceptability and social sustainability are terms used to describe the degree to which a technology is accepted by various societal segments.

IX. Political tact refers to whether the technology may be utilised freely given the complexities and ramifications of the current political environment.

X. The term "administrative manageability" describes how realistically the technology may be used within the current bureaucratic framework.

XI. The degree to which a technology conforms to societal cultural norms and values is referred to as cultural desirability.

XII. The term "renewability" describes how much of a technology may be utilised or reused without significant extra work or input.

XIII. Equitable distribution of the agro-output ecosystems among local farmers and consumers is referred to as equity.

XIV. Productivity is a number that expresses the pace and volume of output per unit of input or area. Production in an ecological sense refers to the yield or final productivity of the process used to produce the end result. One of the elements of sustainable agriculture might be yield per unit area. Other methods of expressing it include ratios of energy efficiency or per unit of labour input or per unit of monetary investment.

Perceptions

Any logic is now defined by the differences in perspectives on sustainable agriculture. While outlining strategies for sustainable agriculture, the Asian Development Bank makes reference to several sources of plant nutrients but leaves out fertilisers, despite the fact that Asian farmers use 40% of the world's fertiliser and that this input is responsible for the production of 500 million tonnes of cereal equivalents (one year's food for 100 million people at one tonne per 5 per sons). FAO, on the other hand, which has undertaken a significant amount of agricultural development work globally. If Asia wants to fulfil the fundamental needs of its expanding population, it cannot avoid using fertilisers heavily in the next years. The issue is not whether to use fertiliser or not; rather, it is the lack of even a fundamental understanding of the elements that might make a system stainable. This is the first restriction from an intellectual standpoint, and it is entirely man-made.

Not all of the resources should be used in a sustainable production system. A pre-planned mechanism should be in place for it to reinvest some of the income in the preservation and enhancement of the A sustainable production system should include a pre-resource foundation to improve its quality and production capabilities rather than relying just on the available resources. Some of these sectors include the improvement of land, water, farming methods, and marketing infrastructure. Thus, agriculture that is sustainable extends beyond cultivating plants and animals.

Elements

Crop diversification, genetic diversity, integrated nutrient management, integrated pest control, sustainable water management, post-harvest technologies, and strong extension programmes are seven areas where promoting sustainable agriculture may succeed.

Diversification of Crops : Crop diversification techniques including double cropping, mixed cropping, and crop rotation have been proven to be effective in various circumstances. Reduced erosion, enhanced soil fertility, and greater production are among of this diversification's main benefits. In the case of legumes cultivated in crop rotation, they also reduce the demand for nitrogen fertiliser.

Rotation of Crops : It is a planting technique that uses several plantings of various crops in the same land. Continuous cropping, which involves planting the same crop again, is the reverse of rotation. Increased soil moisture, pest control, and nutrient availability are all factors that support the beneficial rotational effect. Among them, the advantages of rotation in controlling insects and diseases are crucial. Crop rotation, particularly with legumes, gives extra nitrogen fertiliser

Nitrogen Fixation by Living Things : Another significant and potential area for SA practise is this one. A leguminous crop that fixes atmospheric nitrogen into a form that other crops can absorb may give nitrogen. Leguminous crops provide significant quantities of nitrogen to the soil, however the quantity of nitrogen fixed varies greatly depending on the environment and management practises. Different growers and species also fix nitrogen to varying degrees. The quantity of nitrogen fixed is influenced by a number of physical and administrative variables, such soil acidity or the time of harvest. The ability to conduct SA would be facilitated by a good grasp of the interactions between ecology, plant, microbial, and climatic soil.

Various Cropping : To manage or lower the risk of crop failure, the majority of subsistence farmers in poor nations often mix various crops in the same field. By using these cultivation methods, different crops' rooting systems may access various layers of the soil profile, increasing the total root area that can be used and resulting in a higher total nutrient absorption and overall crop output for the land. It has been discovered that other equally significant reasons for the continuous employment of different cropping systems include an increase in production, an improvement in soil fertility, and the best possible use of water, sunshine, and space. With contrast, in a multiple cropping system, even if one crop is afflicted, there are still other crops that endure, give a harvest, and sustain the farmer. Pest and disease attack on a single crop may result in its complete failure.

Crops' Soil Microbes : Numerous free-living, microorganisms that are connected to plants aid in the facilitation of nutrient absorption. It is well recognised that earthworms play a key role in enhancing soil fertility. Similar to this, it is also widely known how destructive insects, fungus, bacteria, and nematodes can be to crop development in the soil. However, it is still unclear how these bacteria function. Research is required to understand the relationship between crop nutrient requirements and the impact of microbial nutrient cycles.

Genetic Variation : For production to increase steadily over time, genetic diversity and region-specific variety are crucial. Traditional agricultural practises mainly rely on genetic diversity present in the form of many land races. Genetic homogeneity and a high genetic susceptibility to biotic stressors are the results of contemporary agricultural systems. Plant breeding efforts in collaboration with rural communities will result in a diversity of crop types, boosting production stability.

Integrating Nutrient Management (INM) : The phrase "integrated nutrient management" refers to a wide range of practises, including balancing the use of chemical and organic fertilisers, using both organic manures and chemical fertilisers, using biological nitrogen fixation capability, and considering crop management systems. Gaining maximum production or maintaining the current level of yield is challenging, according to the levels of plant country, even if a single nutrient shortage stays unchecked. For effective and sustainable crop production, INM also comprises the use of an appropriate variety, optimal cultural management techniques, and water management. Other than management approaches, fertiliser, farmyard manure, composted crop remnants, green manure, green leaf manure, rhizobium, blue-green algae, and all INM components. Rhizobium systems in legumes and azolla are two more biological N fixation (BNF) systems that are also very important.

Using a system approach to INM of certain crops and cropping systems has been shown to be effective and beneficial due to the complementarity of numerous components impacting the input usage efficiency.

Based on the results of the soil test, correcting nutrient shortages will lead to high yields in soils with low levels of P. Applying N alone won't do much to support growth and yield, but N+P will.

Agronomic strategies such as split fertiliser applications at various development phases, the use of coated fertiliser, granulated fertiliser, methods and positioning of fertilisers, and organic and inorganic binations would provide superior outcomes in terms of output per unit area.

A key strategy to be used in problematic soils to increase sustainability is the employment of green leaf horses.

Combined use of agricultural waste provides productivity, stability, and sustainability over the long run.

Appropriate variety selection and ideal cultural techniques would maintain yield trends.

Implementing water management strategies, such as maintaining agricultural drains, is another element of INM

Pest management that is integrated (IPM) : Sustainable pest management is often referred to as integrated pest management (IPM), which is the integration of strategies to control many pests on one or more crops while maintaining the greatest possible control of each pest. IPM is perfectly used in agriculture to reduce the negative impacts of crop pests by combining the most practical, cheapest, safest, environmentally sustainable, and socially acceptable physical, chemical, and biological approaches. In actuality, IPM is based on an understanding of the ecology of the pest agent and makes the most of the built-in mechanisms for controlling pests. IPM involves more than just looking for pests and using a pesticide after the crop has been grown in the field. It includes actions taken before and throughout the planting of the field, not only after the crop is seeded.

IPM is "A pest management system that, within the context of the associated environment and the population dynamics of the pest species, utilises all appropriate a manner as possible and maintains the pest populations at levels below those causing economic injury," according to the FAO panel of experts (1966–1972). IPM aims to maximise pest control while also maximising total economic, social, and environmental benefits. IPM's overarching goal is to establish and maintain conditions that prevent insects from seriously harming crops.

In several crops, IPM has been effectively implemented using a variety of technologies or components. Use of pest-resistant or tolerant varieties, cultural practises like early or late planting, summer ploughing, use of parasites, predators, and pathogens of crop pests, quarantine measures, hard collection, and destruction, judicious use of pesticides, attractants, repellents, sterilants, growth regulators, male sterile techniques, and suppression campaigns are a few examples. Sustainable pest management (IPM) is still more of an ambition than a reality for the majority of farmers in India since it hasn't yet gained widespread acceptance.

Environmentally Friendly Water Use : In order to improve agricultural output and productivity, water management and use is a crucial input. In low to high rainfall regions of the nation, the distribution of annual prescription ranges from less than 50 mm to more than 2000 mm. Therefore, it is vital to develop appropriate technologies for its use, especially in the nation's semi-arid tropics. For the available surface and ground water resources to be used sustainably, effectiveness in water conservation, equality in water sharing, and efficiency in water transport and usage are crucial. For the conjunctive and proper use of river, rain, ground, sea, and sewage water, a comprehensive strategy should exist. 1) Efficient use of water resources, and 2) providing irrigation water on a volumetric basis so that farmers may utilise it more economically—these are crucial elements in sustainable water management. Thus, the effects of excessive irrigation on the physical, chemical, and biological characteristics of soil may be evaluated. 3) collecting water in the command area. 4) Because groundwater is a precious resource, laws governing the spacing, depth, and volume of water pumped via tube wells—which may be privately built, owned, and operated—are necessary. 5) Proper irrigation system management and design for salinization prevention. 6) Using remote sensing to ensure appropriate groundwater. 7) Effective technology is required for using groundwater and replenishing it. 8) Appropriate funding distribution for electricity, groundwater resource development, and drainage to maximise irrigation potential 9) creation of ecologically sound low cost and medium size dam

Technology used after harvest : The development of value-added goods from the available agricultural biomass and whole-plant utilisation techniques are crucial for increasing revenue as well as for guaranteeing excellent nutritional and consumer acceptability objectives. Low-cost drying, storage, and marketing techniques not only use non-renewable energy sources but also protect agricultural goods from quantitative and qualitative harm. In order to increase farmers' returns, technology should be created for the value-added goods from agricultural products.

Extension Programs, Section : Programs for farmer extension education and communication will undoubtedly aid in spreading awareness of sustainable farming methods. Progressive farmers and Krishi Pandits are now using computer and pest advisories. Computer applications, video cassettes, popular and macular press, farmer periodicals serve to keep farmers up-to-date on newest management system and technological breakthroughs.

These programmes are becoming more popular and are used to establish direct contact between farmers and the many consultants who supply them with the knowledge they need to make management choices. "Social Engineering," which involves the manipulation of the economic effects of a technology or policy being accepted, is a crucial extension approach for SA. For this project, a dedicated extension system is required, especially in resource-poor regions, in order to popularise ecology-based technologies and ensure the success of all the aforementioned components at the farmer's field level.

India's Sustainable Agriculture : Farmers and the Indian community must practise sustainable agriculture if we are to feed a sizable population in the near future. It is well recognised that our nation is overpopulated and that there is significant strain on the non-renewable land that is available. Most of our farmers are small-scale, impoverished, and marginal; they yet want to maintain healthy amounts of both land and water. Therefore, it is necessary to adapt the programmes and policies to the requirements of Indian agriculture. There are farmers available to satisfy future needs. India need a sustainable agriculture that considers the long term and makes wise use of its resources.

SA makes the following recommendations for India:

(A). Preserving the land resource's quality : The productivity of these soils may be restored, and land degradation can be greatly reduced. Increasing the amount of organic matter in the soils should be the first step. This may be done by incorporating as much agricultural residue as possible, adding different types of compost, growing rotational crops that provide organic matter via fallen leaves, and using legumes as green manures. Many nations have supported biogas facilities to provide fuel for cooking in rural areas. These biogas facilities' organic waste is a great source of organic matter for soils. Urban biodegradable garbage has to be routinely composted and sent to farms. Governments may even think about helping farmers transport organic manure from urban regions to rural areas, where farmers often lack access to sufficient supplies of manure.

To increase and preserve soil production, people in developing nations will need to let go of their outdated biases and employ all forms of organic matter, including municipal garbage.

In South Asia, shallow ploughing is typical, and this is what should be done moving forward unless particular circumstances call for deep ploughing. Many nations in the Indian subcontinent have long used a two to three-month summer period during which the land is only lightly tilled and left exposed to the heat. Even if there is a propensity for summer crops to thrive in irrigated regions, this should continue as much as feasible. Soil solarization might be immensely beneficial if inexpensive, biodegradable polymers become widely accessible. Wherever feasible, little tillage is preferred.

There should be more forest land, especially in places with weak soils. No new deforestation should be permitted unless it is well planned. Mulching should be encouraged wherever feasible to stop soil erosion. Vegetables like vetiver should be planted on sloping bunds and other land because they lower erosion rates. By planting parallel edges as wind barriers and mulching the soil, erosion may be significantly minimised. Plantings of legume-filled hedgerows along land Cars considerably reduce soil erosion.

By adding organic matter and cultivating acid- or salt-tolerant plant species, agricultural sustainability on salty or acidic soils may be increased. For generations, raised beds and farrows systems were further enhanced for agricultural planting. Gradated, elevated broadbeds and furrows (slope 0.4-0.89 percent) are extremely effective for vertisol locations where rainfall is mostly guaranteed. Each promotes conservation while lowering erosion. The narrow furrow offers efficient surface drainage. Regarding Alfisols, more advanced technologies must be created for emerging nations. Soybean growing is now being practised in India.

(B). Native American Water Management : Water is a crucial resource for raising land production. The necessity for greater usage of water than is now the case was constantly emphasised. To reach more locations, the canal water distribution system must be enhanced. There has to be desilting of ageing tanks and canals. It is better to use small water reservoirs than big ones. The watershed ideals must be strictly adhered to by communities. hope for effective non-irrigated rain water management. This is accomplished by I increasing soils' ability to hold onto water, ii) using crops to cover as much land as possible during the rainy seasons, iii) harvesting extra water from fields and storing it in local reservoirs (a practise known as watershed concept), iv) avoiding the use of local water reservoirs for growing crops with high water needs (such as paddy and sugarcane), and v) cultivating drought-tolerant crop varieties. Overuse of groundwater must be prohibited by law. Future generations' productivity of irrigated fields must be maintained through projects that increase irrigation water drainage. Efficiency in water consumption should be accompanied by appropriate price. It is worthwhile to try privatising large irrigation infrastructure since government organisations have seldom been effective at managing water resources.

(C). Keeping crop variety intact : There is agreement that agricultural cultivar variety is at risk due to subsistence farming's reliance on elite, high-yielding genotypes. Many worldwide centres, like the CGIAR, retain germplasm today and make it accessible to anybody who needs it. Additionally, there are several gene banks in both wealthy and developing nations. Currently, 16 percent of the world's germplasm collections are held by CGIAR Centers. North America and Europe accounted for around 45% of the collection. The remaining 39 percent is held by various nations, primarily those in Asia, Africa, and Latin America. Utilizing genetic material will involve carefully selecting different agricultural varieties.

(D). Robust agricultural systems : Even though there is a clear transition from subsistence to commercial farming in the majority of developing nations, farmers continue to use their traditional rain-fed methods. It's beneficial for SA if 60 percent of the world's commercial year is spent without a break, like a summer vacation in the tropics or subtropics. It is necessary to reemphasize crop rotations, which are based on well accepted concepts. The study of novel crop rotations will be beneficial. Nitrogen-fixing legumes, crops with various water needs, short-duration crops and cultivars, and crops that would reduce the spread of soilborne diseases and insect pests that impact them should all continue to be included in rotations. Encouragement should be given to relay cropping and intercropping.

The best agricultural systems will be determined through agro-climatological investigations. The start date of the rain might vary by up to a month, but the end date is considerably more predictable. Thus, one may determine which crops or crop kinds should be produced in order to make the most use of rainwater and anticipate the approximate duration of the growing season once the rains start. The best strategy will be crop diversity. 10,000 to 80,000 plant species are thought to be edible, and man has employed at least 3000 species in his diet throughout the course of history. Currently, just 29 species provide about 90% of our food supplies. It is possible to assess novel crop species for food and fibre. The best option for maintaining stable agricultural systems, especially on small farms, is to practise animal husbandry. In reality, to augment their earnings, small farmers in the majority of developing nations raise cattle, pigs, goats, sheep, and poultry. This method requires support, encouragement, and increased profitability.

(E). Using inputs wisely : It will be necessary to continue using chemical fertilisers and pesticides since it is difficult to return to the previous system of no inputs. High sustained yields need these inputs, but they must be handled carefully. Increased yields and long-term sustainability should be guaranteed by the use of organic manures and fertilisers in combination. It will be important to develop new integrated crop health management systems. These need to be founded on: 1) stable and long-lasting host resistance, 2) biological management, and 1) practical cultural methods, especially those that farmers in the ancient world have used for generations. Although it is simple to say that farmers should utilise inputs sparingly, in fact it may be quite problematic for research and extension staff to communicate this idea to farmers, especially commercial farmers in developing nations.

(F) Biotechnology's role : Modern biotechnology has every reason to be expected to advance SA. It is anticipated to aid in :

creating microorganisms that are useful for crop cultivation.

rapid spread of beneficial plant and microorganism species.

For the diagnosis of plant diseases and the identification of harmful residues, new, very effective diagnostics based on the use of monoclonal antibodies and nucleic acid probes,

the introduction of new traits into plant species through genetic engineering,

As a supplement to traditional plant breeding, new genetic mapping methods based on the use of restriction fragment length polymorphisms (RFLPs) are being developed.

production of novel vaccinations and diagnostic tools for projects to improve animal health, and

·application of embryo technologies, particularly to cattle While many other poor nations are unable to do so, several have started organised biotechnology research initiatives. Technology transfer to underdeveloped nations will need international collaboration. In the near future, biotechnology will supplement rather than replace current plant breeding practises.

Farmer assistance from the government : The significance of agriculture has come to the attention of many developing nations' governments during the last 20 years. Governments that are concerned have given these issues attention, and non-governmental organisations (NGO's) are becoming more prevalent. But much more work has to be done. One ministry or agency often oversees defense. The issues of farmers are addressed by several ministries or departments, however, so there hasn't been a lot of attention on them. It will be questioned whether at least some developing country governments could create a single ministry or department for farmers' affairs to focus on all of their economic and social issues and thereby improve and maintain the morale of their country's farmers.

Conclusions

There are various plans that will provide SA to nations like Bangladesh, Sri Lanka, and India. To slow down population increase, however, planning for modest families would be the most crucial step. The only way to ensure food security via SA development is to dramatically slow the current rates of population expansion. Better health care and rising literacy rates, particularly among women, will have a significant impact on population decline. It will be necessary to raise public awareness, particularly in rural regions, and NGOs might play a significant role in this. Small family incentives will need to be implemented. Other issues that need attention include changes in eating habits and public cleanliness. The key determining factors that have led to the huge exploitation of natural resources, such as land, water, and wildlife, include the growing population, extensive industrialisation, agricultural transformation, underdevelopment, etc. Therefore, there is a need for sustainable development, which implies the programme should be supportive of the environment, the economy, and society. A particular programme is required for the collection, assessment, and development of genetic resources for the promotion of long-term improvements in crop yield in order to attain agricultural sustainability. Sustainable agricultural productivity can be achieved in part through the scientific management of water, better use of degraded soil, adoption of inland fisheries, aquaculture, and livestock, establishment of small-scale agro-processing industries in rural areas to support rural economy, education of women, etc. Paying attention to agricultural, livestock, and agroforestry production can assist create more employment and revenue.

Participatory research and training are a basic necessity for sustainability. Without enough engagement from the public in terms of education, information, training, and effective participation, agricultural output cannot be sustained.Finally, given the urgency of the situation, we must develop practical plans and methods for implementing SA throughout the nation in each agro-ecological zone and its sub-zones before the turn of the century.

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Chapter 3

Management of Citrus and Mango Diseases through Organic Practices

Vijay Kumar* and Lakhanapuram Hemanth Kumar
College of Horticulture, VCSGUUHF, Bharsar, Pauri Garhwal
**Corresponding Author Email : vijaykumar.india28@yahoo.in*

Abstract

Organic agriculture may be described as an included farming system that strives for sustainability, the enhancement of soil fertility and organic range whilst, with uncommon exceptions, prohibiting artificial pesticides, antibiotics, synthetic fertilizers, genetically modified organism. Disease management strategies in organic farming are Growing disease resistant varieties, Exclusion of pathogen, Application of organic amendments, Cultural control, Orchard bio-intensification, Physical methods, Botanicals, essential oils, baking soda, butter milk etc, Application of biocontrol agents, Application of mineral-based fungicides. Biochemically efficient strain *of Pseudomonas fluroescens* Pf IV was found effective. *P. parasitica*. that, among the tested species of bacteria viz. *Bacillus subtilis*, *B. polymyxa*, *Pseudomonas fluorescens* are effective.

Key words : *Organic farming,disease resistant variety, organic amendments, Trichoderma harzianum, antagonism, Pseudomonas fluroescens, Xanthomonas compestrispv. Citri, Bacillus subtilis.*

What is organic farming?

Organic agriculture may be described as an included farming system that strives for sustainability, the enhancement of soil fertility and organic range whilst, with uncommon exceptions, prohibiting artificial pesticides, antibiotics, synthetic fertilizers, genetically modified organisms, and growth hormones. It is based on fertilizers of natural foundation together with compost manure, green manure, and bone meal and locations emphasis on techniques which includes crop rotation and other cultural practices. It promotes soil fitness and carbon sequestration and offers more than one environment offerings inclusive of mitigation of weather change. Integrated natural farming gadget will now no longer simply promote organic food production however additionally lessen dependence on outside assets through efficient recycling of on-farm biomass and different assets specifically disease control nevertheless stays an actual challenge. The soil fertility is maintained with the aid of using returning all of the residues to it thru composts, thereby, minimizing the distance among nutrient addition and elimination from the soil (Chhonkar, 2002). The principle of plant nutrition in organic farming is 'feed the soil not the plant'.

National programme for organic production (NPOP)

Organic products are grown under a system of agriculture without using chemical fertilizers and pesticides with an environmentally and socially accountable approach. This is a method of farming that works at grass root degree keeping the reproductive and regenerative capacity of the soil, good plant nutrition, and sound soil management, produces nutritious food wealthy in vitality which has resistance to diseases. India is bestowed with lot of ability to produce all forms of organic products because of its

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various agro climatic conditions. In several elements of the country, the inherited tradition of organic farming is an added advantage. These holds promise for the organic manufacturers to faucet the marketplace that is developing step by step withinside the home and export sector. As in keeping with the to be had statistics, India's rank eighth in phrases of World's Organic Agricultural land and 1st in phrases of general variety of producers as in keeping with 2020 data.

Disease management strategies in organic farming

Occurrence of a disease requires a balanced interaction of host, pathogen, and environment. The disease management strategies under organic farming aim to disrupt this balance and disallow the pathogen to cause disease beyond economic injury level. Pathogens need suitable environmental conditions like humidity, temperature, moisture, host exudates etc to germinate, survive and infect. In absence of these pathogens cannot survive and perish. Most of the strategies described below interfere with the micro-environmental conditions to make them uncongenial for pathogen propagation, multiplication and initiating infection. Further majority of these strategies are specific to particular disease in a crop and hence a combination of strategies based on the crop growth stages and disease cycle need to be integrated as a module for a crop in a particular agro-climatic region.

Growing disease resistant varieties : For low external input organic farming, resistant crops represent an important alternative to pesticides. Exploiting the diversity and variability in the host genetic constitution for resistance against a pathogen in a crop is the best strategy for disease management without application of hazardous pesticides. It can individually restrict the incidence of a particular disease in a crop. Successful disease establishment depends on the compatible gene for gene interaction between a host and a pathogen. Resistant varieties tend to remain disease free for a long period of time owing to morphological manifestation of their genetic constitution in form of leaf and stem toughness, time of maturity, nutrient content, plant architecture, growth habit which can deter growth of pathogen, their reproduction and host preference. Care needs to be taken to include more than on resistant variety in a region to dissipate selection pressure on the pathogen. However, this strategy is very specific and tends to tackle only one or two diseases at a time owing to its resistance.

Exclusion of pathogen : Preventing the potent and viable disease propagules to interact with the host results in reduction in disease incidence. Use of disease-free seeds and planting material would prevent seed borne disease, management of vectors, and in situ destruction of soil borne pathogens through soil solarisation or Anaerobic soil disinfestations (ASD) involves the incorporation of fresh organic material in moist soil under airtight plastic for 3–6 weeks, depending on the outside temperature (van Bruggen *et al*., 2016; Khulbe, 2000).

Application of organic amendments : Soils with low microbial diversity promote establishment of plant pathogenic organisms. Healthy soil is the mainstay of organic agriculture. Improved soil biological activity is known to play a key role in suppressing weeds, pests and diseases (IFOAM, 1998). Improving soil health through use of cover crops, green manures, animal manures to fertilize the soil not only helps in restricting soil borne pathogens but also maximizes biological activity and maintains long-term soil health. Application of composts and organic amendments tends to increase quantity and diversity of soil microbial diversity and consecutive disease suppressiveness. Organic amendments are biodegradable and are generally available on the farmer's fields. Neem cake used for soil amendment @ 0.25 to 0.5 t/ha contributes significantly in control of nematodes and soil borne pathogens. Soils rich in organic matter are high on soil biodiversity with abundance of beneficial soil microorganisms.

Cultural control : Cultural control is more like habit of good agricultural practices, which promotes healthy soils and healthy plants. From choosing the date of planting to field sanitation and weed management, the specific cultural measures reduce the initial load of inoculum and favourable conditions for growth of pathogens. Rotations can also be designed to minimize the spread of weeds, pests and diseases. Litterick *et al.* (2002) opined that pest control strategies in organic farming systems are mainly preventive rather than curative. The management of cropped and un-cropped areas, crop species and variety choice and the temporal and spatial pattern of the crop rotations is actually aimed to reduce interaction between susceptible host and virulent pathogen while maintaining a diverse population of beneficial organisms in the field. The development and implementation of well-designed crop rotations is central to the success of organic production systems (Stockdale *et al.,* 2000). However, crop rotation can be ineffective if the pathogen is long-lived in the soil with a wide host range. Ensuring good drainage is essential for disease management. Poor drainage in the fields not only reduces general health of the plant but also allows the pathogen to multiply rapidly. Many pathogens can survive on debris and weeds. Tilling and cleaning of plant residue at the end of the season allows break down of the organic matter, leaving potential pathogens without a host. Moderate fertilization induces steady growth and makes a plant less vulnerable to infection.

Orchard bio-intensification : The orchard bio-intensification concept envisages habitat modification for beneficial organisms, development of healthy and biologically active soils, maintaining uncultivated lands for diversity of flora and fauna, developing entomophage parks within orchard for food and shelter to diverse beneficial insects, weed strips, hedge rows, wind breaks, inter crops and conservation of insect bio diversity (Singh and Srinivas, 2016).

Physical methods : Soil solarisation of nursery beds reduces soil borne inoculum. Hot water, steam treatment of seeds, planting material has been successful in many crops (Cohen *et al*., 2005). Post-harvest hot water treatment of mango fruits was able to reduce the incidence of anthracnose (Srinivas *et al*., 2012).

Botanicals, essential oils, baking soda, butter milk etc : Spraying of neem oil, cow urine, panchgavyaand fermented butter milk are some of the most predominant methods of controlling pests and diseases by the organic farmers in India. Several researches indicate that application of many plant extracts may reduce incidence of foliar diseases. Application of horticultural grade oils has also proven to reduce disease incidence in many crops. Baking soda has been used to control mildew and rust diseases on plants. Application during hot weather and may though lead to possible phytotoxic effects. Butter milk sprays have been popular against blights, mildew, mosaic viruses and other fungal and viral diseases. Application of soft soap solutions and neem oil against viral vectors like aphids and other sucking insects is also effective. Cow dung ferments like 'Amrit-Paani' are widely used by organic farmers for enhancing crop growth and disease management. Such fermented solutions are known to have high bacterial population of cellulose degraders, nitrogen fixers, P-solubilizers, plant growth promoters and antagonists of disease-causing fungi (Venkateswarlu *et al*., 2008).

Application of biocontrol agents : Microbial bio-control agents isolated from native environments are relatively safe, host specific and do not disturb other biotic systems (Srinivas and Ramakrishna, 2005). They are ideal for both short- and long-term pest suppression and are also compatible with most other control methods. Their mechanisms of action include competition, antagonism, antibiosis, enhanced nutrient uptake, induction of host resistance (Kloepper *et al*. 1997) etc. Unlike chemical pesticides, they are harmless to humans and other non-target organisms, they do not leave chemical residues on crops, are easy and safe to dispose of and do not contaminate water systems. Commercial bio-fungicides are containing beneficial living organisms are can be locally produced and used for pest management in Organic farming. These are available as powders for seed treatments, as granulars for soil application, and as suspensions for root drenches and foliar sprays. Biological control agents like *Trichoderma*spp, *Pseudomonas*spp and *Bacillus* spp. have proven their worth in managing a range of plant diseases. Some of them have also shown to promote plant growth too.

Application of mineral-based fungicides : Prophylactic sprays of Sulphur are mostly used against plant diseases like powdery mildew, downy mildew and other diseases by preventing spore germination. Copper based fungicides and Bordeaux mixture (Copper sulphate and lime) have been successfully used on fruits, vegetables and ornamentals. Unlike sulphur, Bordeaux mixture is both fungicidal and bactericidal. It is effective against diseases such as leaf spots caused by bacteria or fungi, powdery mildew, downy mildew and various anthracnose pathogens. The ability of Bordeaux mixture to persist through rains and to adhere to plants is one reason it has been so effective. Copper hydroxide and copper oxychloride are accepted in organic farming provided that the number of applications is moderated to prevent copper accumulation in the soil.

Examples

Organic management of *Phytophthora* spp. In citrus

Damping-off : Damping-off of Citrus seedlings is caused *by Phytophthora parasitica*, *P. citrophthora* and *P. palmivora.* Typical symptoms of damping-off result when the soil-borne fungus penetrates the stem just above the soil line and causes the seedling to topple. *Phytophthora* spp. also causes seed rot or pre-emergence rot. Infected seedlings are killed rapidly when moisture is abundant and temperatures are favorable for fungal growth (Naqvi, 2000).

Foot rot and gummosis : Foot rot results from an infection of the scion near the ground level, producing lesions which extend down to the bud union on resistant rootstocks (Fawcett, 1936). When susceptible rootstocks are used scaffold root rot or crown rot below ground may occur. Infected bark remains firm with small cracks through which abundant gum exudation occurs. Citrus gum disappears after heavy rains but remain persistent on the trunk under dry conditions. Lesions spread around the circumference of the trunk, slowly girdling the tree (Timmer and Menge, 1993)

Root rot *Phytophthora* spp. : Infects to the root cortex which starts decaying of fibrous roots. The cortex turns soft, becomes somewhat discolored and appears water soaked. After severe infection cortex of fibrous roots get destroyed leaving only the white thread-like stele, which gives the root system a stringy appearance. This results in the reduction of fruit size and production, loss of leaves and twig dieback of the canopy (Timmer and Menge, 1993).

Brown fruit rot : When fruits are infected by *Phytophthora*, it produces a decay in which the affected area is light brown, leathery and not sunken compared to the adjacent rind. Under humid conditions, white mycelium grows on the rind surface.

In the orchard, fruits near the ground become infected when splashed with soil containing the fungus. In storage, infected fruit have a characteristic pungent, rancid odour. Brown rot epidemics are usually restricted to areas where rainfall coincides with the early stages of fruit maturity (Timmer and Menge, 1993).

Several studies reported some potential biological agents for *Phytophthora* management in citrus. Gade (2012) reported that, *in vitro* antagonism showed by *Trichoderma harzianum* and *T. virens* (84.96%) suppress *P. parasitica* significantly. Intensity of antagonism was different as per medium but, there was a continuous reduction in pathogen population from 41 to 8 propagules/g soil with reduction in root rot /collar rot in *Citursjambhiri*. All Thirtyseven native isolates of *Pseudomonas* spp. were found positive for production of IAA, HCN and Siderophore. Pf XXVI (16.80%) and Pf IV (24.10%) were found effective to manage the disease in addition to increased growth response under glass house condition. Biochemically efficient strain *of Pseudomonas fluroescens*Pf IV was found effective to arrest the percent mycelial growth (55.20%) of *P. parasitica* .

Gade and Koche (2012) reported that, *Pseudomonas fluroescens* in combination with fungicides and organic amendments (module IV) was found effective in management of root rot and gummosis in Nagpur mandarin. There was consistent reduction in population density from 24.33 cfu/cc soil in May 2008 to 6.20 cfu/cc soil in May 2010 of *Phytophthora* spp. in module IV. Significant decrease in intensity of root rot and gummosis was recorded where integrated management module (module IV).

Root rot intensity was reduced in this module from 36.18 % initially to 16.70 % at the end of the experiment. Similarly, significant reduction in gummosis up to 54.76 per cent was recorded in the same module. *Trichoderma viride* inhibits highest mycelial growth of *Phytophthora paracitica* (75.33%) in vitro, whereas, under glass house experiment combined application of *Trichoderma viride* @ 4g/Kg +Garlic clove extract @ 5% significantly reduced percent root rot incidence (11.32%) as compared to untreated control (44.99%) (Pente *et al*., 2015).

In vitro studies of Heller and Hedtrich (1994) suggested that, *Chaetomium globosum*, *Gliocladium virens* and *Trichoderma viride* are effective inhibitors of all the *Phytophthora* spp. tested including *P. nicotianae*.

Organic management of citrus canker

Citrus canker is one of the major citrus diseases which affects all types of important citrus crops. The disease is endemic in India, Japan and other South-East Asian countries, where it has spread to all other citrus producing continents except Europe. However, widespread occurrence of the disease in many areas is a continuous threat to citriculture especially in canker free areas.

Studies on biological control of citrus canker are still in a preliminary stage. Some strains of bacteria viz., *Pseudomonas syringae*, *Erwinia herbicola*, *Bacillus subtilis* and *Pseudomonas fluorescence* isolated from citrus phylloplane were reported to be antagonistic *in vitro* to the canker pathogen (Ota 1983; Goto*et al*., 1979; Unnimalai and Gnanamanickam,. However, it seems difficult to find antagonistic bacteria that reside stably on smooth surfaces of mature citrus leaves.

An experiment was set up by Das *et al*., (2014) in a farmer’s field (acid lime orchard) using an inhibitory strain of *Bacillus subtilis* (S-12) showed that, single spray of aqueous suspension (2.7 x 109 cells/ml) of bacterial cells was spread on 5 batches (6 numbers of plants/batch) of plantskeeping 4 batches unsprayed. Per cent Disease Index (PDI) was recorded throughout the year at every month. Initial PDI was also taken before one week of spraying. A single spray of the bacterial suspension during the peak season for disease that is in July has resulted in a satisfactory decline of the disease. A sharp decline of the disease was recorded at 20 days after treatment indicating that the spore forming bacteria might have taken over on the leaf surfaces of the plants.

Kalita *et al*., (1996) reported that, among the tested species of bacteria viz. *Bacillus subtilis*, *B. polymyxa*, *Pseudomonas fluorescens*, and three species of fungi viz. *Aspergillus terreus*, *Trichoderma viride* and *T. harzianum* isolated from the phylloplane of citrus variety Assam lemon (Citrus limon) inhibited the growth of *Xanthomonas compestris*pv. *citri*, *in vitro*. When the antagonists were tested for their efficacy under field condition by applying them over crop foliage of Assam lemon, they also reduced citrus canker incidence and *Bacillus subtilis* was found to be most effective antagonist exhibiting maximum (14.7 mm) inhibition of the pathogen and reducing the disease incidence to an extent of 61.9 per cent.

Organic management of Mango

Mango orchards are the permanent ecosystems, akin to forest ecosystems, with certain human interventions. However, the pest population is not in equilibrium in orchard ecosystems as observed in undisturbed forests. However, such natural balance is disturbed in the orchard ecology due to regular cultivation practices especially application of chemical pesticide. Several pests and diseases occur in the organic plots similar to the non-organic plots. However, the options for pest management in these plots are limited. Major emphasis is given in bio-intensification of orchards, application of mineral-based fungicides, and application of botanicals. For management of foliar leaf spots and anthracnose in leaves and fruits, application of copper-based fungicide is done based on the observations of field scouting. The downy mildew disease affecting the inflorescence is managed by application of sulphur-based fungicides with prescribed precautions. Field sanitation, proper plant architecture, and application of enriched organic amendment are the mainstay of disease management in the organic mango cultivation. Further, for long term sustainable pest and disease management there is a need to strike a balance for appropriation of various interventions for suppression of pests, which can be achieved through orchard bio-intensification (Singh and Srinivas, 2016).

Disease management in tree crops grown in organic conditions is a challenging task due to limited and unproven options available. Higher powdery mildew and black mildew severity was observed in case of organically grown plants compared to control plants probably due to luxurious growth in the former (Srinivas and Singh, 2011). Different combinations of ecofriendly disease management options were evaluated for their efficiency against powdery mildew and red rust in mango (cv mallika) orchard under organic mode of cultivation at the Station. Treatments viz. Milk (10%), Vermiwash (10%), Cow urine (10%), Neem oil (0.2%). Sulphur (2g/l), and their combinations were imposed in mango plants grown in two nutrient levels (5 kg and 7.5 kg farm yard manure first year basis). The dosage of the manure was increased by 100 percent of the initial FYM dosage every year. Two control treatments of spray with plan water and no spray were also maintained. The disease score of powdery mildew was found to be least in case of the treatments with sulphur and neem oil, while highest disease was observed in treatments with milk and plain water. Incidence of the red rust was least in treatments with sulphur, neem oil and control plots.

There was a marked difference in the incidence of powdery mildew disease among the treatments. The 10 kg treatment plot was relatively free (37.7% incidence) from the powdery mildew disease followed by the negative control plot (34.4% incidence). In contrast highest disease powdery mildew incidence was observed in positive control plots (87.0% incidence) closely followed by 5kg and 7.5kg plots with 76.8% and 76.3% disease incidence. Though it was interesting to note that there was comparatively low and delayed flowering in 10kg and control plots, which also had lower powdery mildew incidence (Srinivas *et al*., 2010). Further the 5kg, 7.5kg and RDF plots contained more trees with inflorescence with higher coverage of the powdery mildew fungus (60% and more area of inflorescence). Based on the data of first three years of experimentation it is concluded that there is no significant negative effect of organic mode of cultivation in the major growth parameters and powdery mildew incidence.

Do's and Dont's in Organic Farming

Do's in Organic Agriculture

Climate Appropriate to avoid pests and diseases

Soil type to match with the crop cultivated. Ex: Deep well drained soils.

Crops With inbuilt disease, pest & other biotic resistance.

Acceptability for markets Quality,

Yield potential Adaptability to varying environmental conditions

Climate, soils, crops-Appropriateness and suitability are the key factors to be considered Pesticides and organic agriculture No processed chemical pesticide is approved for use. Instead of chemical pesticide the following can be used Botanicals Neem based products Pongamia based product Any botanical with pesticidal property Biocontrol or biological control agents such as *Bacillus thuringensis* (BT)

Natural enemies of pests can be used Adopting natural biocontrol measures such as Mixed cropping Trap crops etc. (Panchakavya, agnihotram,homeo medicines, vrikshayurveda are also projected as effective No chemical pesticide is the major requirement for O.A.

Do not use Agrochemicals Fertilizer : Agrochemicals such as pesticides, herbicides, fungicides, plant growth promoters (synthetic hormones) Antibiotics for crop production.

Do not use products like Antibiotics, pest control chemicals, hormones, disinfectants, urea etc for Livestock production

Any processed input considered to be a potential environmental hazard is prohibited Specific items banned in organic crop production Sewage, sludge, Genetically engineered crops Ionizing Radiation for food processing.

Chemical preservatives Land for organic agriculture should NOT have used prohibited products/ substances for minimum three years.

Banned items in the "Specifics" list should be checked with standards and certifying agencies as they change from time to time Thus, organic way of pest and diseases management plays a significant role in organic farming.

The knowledge intensive and farmer-based management approach that encourages natural control of pest populations by anticipating pest and disease problems and preventing from reaching economically damage levels will definitely help achieving the target yield without causing serious damage on environment and contaminating the food.

Conclusions

Citrus and mango diseases can be minimized by using disease resistant variety,application of FYM, cultural practices, Treatments viz. Milk (10%), Vermiwash (10%), Cow urine (10%), Neem oil (0.2%). Sulphur (2g/l), Bioagent *Trichoderma harzianum* (5g/lit) *Pseudomonas fluorescene* (5g/lit). Bacillus subtilis 5g/lit are effectie for the control of Citrus and mango diseases.

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Chapter 4

Vertical Gardening of Vegetable Crops–Need of the Hour

Meenakshi Badu[1,2*], Gouri Shankar Sahu[1] and Pradyumna Tripathy[1]
[1]*Department of Vegetable Science, College of Agriculture, Odisha University of Agriculture and Technology, Odisha, India*
[2]*Faculty of Agriculture, Sri Sri University, Cuttack, Odisha, India*
**Corresponding Author Email : badumeenakshi@gmail.com*

Introduction

Vertical gardening is an approach used to grow vegetables up and down, rather than side to side like in a traditional horizontal garden. In a vertical garden, vegetables grow up tall structures instead of across the ground. Vertical gardening is an alternative for gardeners with limited space. The term vertical garden refers to any kind of construction and support structure for growing plants in an upward-directed, vertical way and thereby efficiently and productively making use of the existing space. Grow up tall structures instead of across the ground. It is a new concept of gardening, which had been developed in Switzerland.

Concept

Creating gardens "up" instead of "out".

Revolution of Agriculture.

Idea of vertical garden first developed by NASA for raising the food crops in unlikely habitat and climate.

Design depends on available material, space and local preferences as well as on the creativity and imagination of the users.

Crops *viz.* food crops (vegetables, fruits, herbs) and non-food crops (ornamental plants, medicinal plants) can be grown.

History

The hanging garden of Babylon was the earliest known garden.

In 1915, the American geologist Gilbert Ellis Bailey used tall multi-storey buildings for indoor cultivation.

The Father of vertical garden is Patrick Blanc.

In 1999, Dickso Despommier had given concept of vertical farming (Royston and Pavithra , 2018)

The popularity surge could be attributed to the release of Despommier's book in 2010, *"The Vertical Farm: Feeding the World in the 21st Century"*

Need of vertical garden

During 2050 there is an estimation of around 70% of world population will be in urban centres.

The global population is expected to reach a staggering of 9.7 billion by 2056 (Kumar, 2019)

As it is an eco – friendly method of cultivation, popularity is increasing day by day.

More food can be produced by using less resources.

Vertical gardening for different class of people

Plant lovers and gardeners- fun to practice vertical gardening within limited spaces.

Educators-provides a creative and exciting hands.

Health-conscious consumers- an organic growing system, provides fresher and cleaner vegetables.

Business-minded persons - who lack for farm land, serves as a production system which may

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create a niche market for vegetables, herbs and fruits.

Vertical gardening helps in…

To mitigate climate change
Aesthetics
Building Protection
Indoor Air Quality
Acoustics
Health & Wellness
Sustainability
Ecosystem stability
Relocate or replant

Points to be remembered before construction (www.wikihow.com/Grow-Vegetables-Vertically)

Determine where to situate the vertical garden : Most vegetables require at least 6 hours of sun, so choose a sunny location for the vertical garden. If you live in an apartment building, a sunny balcony may be an option. If you have a yard, consider a sunny location against a south-facing wall of your house.

Select vertical structures : In order for plants to grow vertically, they need a vertical support system. Common support structures include trellises, tripods, pyramids, walls, fences, wire cages and walls. Arches or arbors can serve as focal areas while also supporting vegetables. Almost any structure that points toward the sky can be used for vertical gardening. Consider creative options like bamboo poles, tree branches, ladders, sunflowers or corn stalks.

Choose a support structure strong enough for the vegetables you want to grow. Mature plants loaded down with vegetables can be heavy. For example, tomato plants require very sturdy vertical structures, while peas may climb almost any structure without bearing much weight on it.

Place the support system in your garden or on your patio before planting vegetables. This prevents you from damaging plants.

Locate vertical supports on the north or east side of the garden where they won't block the sun from the growing vegetables.

Anchor the support system securely. Vertical supports like trellises or wire cages can be staked directly in the ground. Trellises and other flat vertical supports also can be attached to the exterior wall of a home. If you attach a vertical support to a wall, leave space between the wall and the trellis for air circulation as the plant climbs.

Prepare the media

Whether we are planting vegetables in the ground or in containers, soil quality is important for vertical garden. Use weed-free, compost-rich soil. To encourage proper drainage in containers, mix the soil with peat moss or perlite.

Choose containers as applicable

If we are growing vegetables in containers, we can use almost any type of container. Make sure that the container is deep enough to accommodate the type of vegetable you are growing. Larger and heavier vegetables will require larger and sturdier containers. Consider hanging baskets, urns, window boxes, washtubs, coffee cans, clay pots or wooden crates. If the container does not have drainage holes, drill small holes on the bottom of the container before filling it with soil.

Things required for construction

Vertical support structures
Vegetable seeds or seedlings
Compost-rich soil/coco peat
Peat moss or perlite
Containers
Water/soluble fertilizer
Cloth twine or strips of fabric
Polythene sheets
Garden gloves
Small knife or pruning shears

Key factors for choosing growing system

Space
Power access
Light availability
watering and drainage
Ventilation
Pest management
Growing media
Crop choice
Orientation

Vertical growing ideas

(www.growveg.com/guides/ideas-for-small-gardens-growing-vegetables-vertically/)

A-frames : These can be made from wooden trellis, horizontal battens of wood or netting held taut between the two frames. Lean the frames together and secure at the top with wire or hinges. Grow climbers up the two frames and use the space between to grow plants that will appreciate shade during the warmer summer weather: salad leaves and spinach for example. A well-constructed frame can be used year after year – just pull it free from the ground at the end of the season and store in a shed or garage.

Living wall : Invest in one of the many wall or fence-mounted modular planters or panels available. Fabric Woolly Pockets are just one example. There are also many stackable planters that can be built from the ground up. Plant them up with herbs, salads and strawberries and watch a blank space take on a whole new life.

Hanging about : As well as growing up from below, many climbing or sprawling edibles can be grown from above and left to hang down. Vine tomatoes are best for this and work well in 'upside-down' planters. Make a hole into a large bucket that's just big enough to allow you to plant up the tomato. The hole must also allow the stem to thicken as the plant grows. Plant the tomato, feeding compost around the root-ball and fill to the top of the bucket. Sow or plant at the top shallow-rooters such as lettuce, radish, basil or stump-rooted carrots. Hang up then feed and water from above while the tomato erupts out from beneath. We can also grow strawberries and other fruiting vegetable such as peppers and eggplant in this way.

Edible divider : An edible divider is far more attractive than a solid conifer hedge or artificial alternative. Espaliered fruit trees (where the branches run parallel to each other in horizontal rows) make excellent natural dividers. Train the trees onto trellis to provide an all-year-round divider and plant the base up with annual vegetables or flowering herbs such as rosemary to keep pollinating insects busy for longer. Annual climbing vegetables such as peas and beans make excellent seasonal screens and have the bonus of being very quick growing.

Archway of delights : Visitors will immediately know you're a passionate grower of all things edible if you plant an edible archway leading up to your front door. Simply plant each archway support with its own climber and watch as over the growing season the archway is consumed by a lush jungle of foliage, pods and fruits. Squashes and beans with colored pods (try alternating purple and yellow-podded varieties such as 'Blauhilde' and 'Goldfield') look especially impressive given this treatment. The pods and fruits will dangle down above head height to create quite a visual impact. Beans with strongly coloured flowers such as the classic 'Scarlet Emperor' are as floriferous as the best of the traditional ornamental climbers – a feast for both the eyes and stomach.

Different Vertical Garden Designs

Cultivation arches, cultivation towers or cultivation bags can be used.

Variety of different substructures like cultivation ladders, pyramids or racks can be designed.

Walls, murals and exterior walls of houses-vertical gardening alternative either just as beautification of the wall or to grow vegetables and other crops along the wall.

Wall will be modified with additional bricks or holders can be used for growing plants on the surface of the wall.

Types of vertical vegetable garden (savvygardening.com/vertical-vegetable-garden)

Salad tower : This is a cylinder built from a sturdy wire mesh, lined in plastic and filled with soil. To build, bend a 6 foot tall section of metal mesh (like concrete reinforcing wire or a chicken wire-like mesh with holes at least 4 inches square) into a two-foot diameter cylinder. Line with a garbage bag or a large plastic sheet. Fill with moist potting soil. Poke holes or cut an X through the plastic and slip a seedling into the cylinder, making sure the roots are pushed into the potting soil. Continue to plant seedlings all around the cylinder. Water well and feed every two weeks with a liquid organic food. Mix and match lettuce, arugula, spinach, chard, Asian greens, and kale for a tapestry of greens.

Hanging garden : A hanging basket takes up no ground space, but can offer a bumper crop of sweet strawberries or tumbling tomatoes. Hang the basket in a sheltered sunny spot, and water and feed often.

Pallet garden : Pioneered by Fern Richardson, author of small space container gardening (Timber Press, 2012), pallet gardens have become a huge garden trend in recent years. A pallet garden is an easy and effective way to grow compact vegetables and herbs like salad greens, baby kale, dwarf peas, bush beans, parsley, thyme, basil, and rosemary as well as edible flowers like pansies and calendula.

Gutter garden : Plants like curly parsley, alpine strawberries, lettuce, spinach, 'Tiny Tim' tomatoes, and nasturtiums are grown.

Window Box wall : One of the easiest ways to grow food vertically is to secure window boxes nor individual pots to fences and walls. To really stand out, paint the containers with bright colours before they are hung. Planting can be done with compact herbs, vegetables, and strawberries.

Selection of plants for vertical garden

Climbing vines (pole bean, pea, cowpea, cucumber, basella)

Trailing vines (watermelon, pumpkin, sweet potato)

Crucifers

Solanaceous vegetables

Root and bulb vegetables

Greens (lettuce, spinach, swiss chard, red amaranth)

Micro-greens and baby greens (red amaranth, beet, basil)

Operation and Maintenance

Regular water and nutrient supply needs to be ensured.

Irrigation techniques like bottle irrigation or regular watering with watering cans.

Plant nutrients like nitrogen, phosphorus and potassium should be applied according to the needs of the plant.

Use of treated or partly treated grey water and reclaimed water can also be a cost effective alternative water and nutrient source particularly in water scarce areas.

Advantages

Reuse and recycling option for biodegradable wastes and grey water.

Temperature insulation by growing plants on the walls of houses.

Reduction of "food miles".

Reduce transportation cost.

Excellent opportunity of growing food in areas where space is limited.

Effective and sustainable method.

Implemented with locally available material at low cost.

Disadvantages

Unpleasant odours may appear during the irrigation with grey water.

A certain amount of labour required.

Regular watering or irrigation system has to be in place.

May affect building.

Arka vertical garden (https://iihr.res.in/arka-vertical-garden)

Can be used by anyone who desires to grow vegetables, medicinal and flower crops using vertical space.

Pots suitable for growing different vegetables, flowers and medicinal plants can be used with soil or soilless (coco peat) growing medium.

Can be accommodated in floor area of one square meter.

Consumer also controls the use of fertilizer, pesticide and inspective to its safe limit and he also knows what he consumes.

Structure suitable for handling in terms of height of reach, mobility, requirement light available to all the pots.

Effective utilization of maximum area for growing plants.

Plants like tomato (pot size-16" dia. and 12" height), chilli, brinjal, French bean, peas etc., (pot size- 12" dia. and 10" height) – lower level.

Leafy vegetables like amaranthus, coriander, palak etc., (pot size- 26" x 8"x 6" (LxWxH)) and medicinal plants like brahmi, pudina, pepper mint, ashwagandha, shatavari etc., (pots size -14" x 8"x6" (LxWxH))- upper levels.

25 litre plastic container at the top.

Yield of 200 g to 5 kg of produce.

Cost-Rs. 22, 000.

Vertical farming

It is a system of growing crops and producing foods in vertically stacked layers, such as skyscrapers or shipping containers.

The modern ideas of vertical farming, use indoor farming techniques and controlled environment agriculture (CEA) technology, where all environmental factors can be controlled such as artificial control of light, humidity, temperature *etc*.

Types of Vertical Farms

Type 1 - Tall structures with several levels of growing beds.

Type 2 - On the rooftops of old and new buildings

Type 3 - multistorey building. (Despommier, 2014)

Systems used in vertical farming

1. **Vertical hydroponics**

   Most widely used

   Soil replaced by nutrient solution.

   NFT and Deep water culture.

2. **Vertical aeroponics**

   Misting of roots with no growing media

   Uses less water than hydroponics

   Plants uptake more minerals and nutritents

3. **Vertical aquaponics**

   Blend of aquaculture and hydroponics

   Not widely used

Scope and potential of vertical farming

Less deforestation and land use.

Abandoned or unused properties will be used productively.

Crops will be protected from harsh weather like floods, droughts etc.

Reduction in vehicular transport as the crops produced is easily consumed.

vWater is used more effectively.

Suitable crops for vertical farming

Current model-high value, rapid growing, small-footprint and quick turnover crops.

Many leafy vegetables - basil, lettuce, microgreens, kale, spinach, palak etc., and tomato, radish greens, peppers.

Further research is needed to grow staple crops like potato.

Advantages of Vertical Farming

All year round crop production.

Avoidance of droughts floods and pests.

Water recycling.

Less amount water and nutrients needed.

Reduction in use of fossil fuels (no tractors, farm machinery or shipping).

Quality and fresh food to consumer and creation of new jobs.

Limitation in vertical farming

Limited vegetable crops have been identified for the purpose.

No varieties/hybrids - exclusively bred for the purpose of vertical farming.

Production technologies and Good Agricultural Practices for these crops have not been standardized.

Conclusion

Start-up costs can be high

This technology is still relatively new.

Controlled environment vertical farming with red and blue LEDs is most suitable to maximize the productivity of vertical farming.

Vertical aeroponics is most suitable to increase the crop productivity.

Future thrust

State and central agricultural universities should be focused on vertical farming research to improve the more productivity.

Still more research need to improve the lighting and nutrients technology.

Suitable hybrid and varieties have to be developed.

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Chapter 5

Omics Strategies to Combat Abiotic Stress in Pearl Millet

Kajal Nagre[1*], Nirupma Singh[1], Chandrika Ghoshal[2], Anita Meena[3] and S.P. Singh[4]

[1]*Division of Genetics, ICAR-IARI, New Delhi*

[2]*Division of Vegetable Sciences, ICAR-IARI, New Delhi*

[3]*ICAR-CIAH, Bikaner, Rajasthan*

[4]*CSAUAT-Agriculture Research Station, Kalai, Aligarh, Uttar Pradesh*

Abstract

Through revolutionary technical improvement over the past few decades, the analytical procedure needed for omics investigations has become simpler, quicker, more accurate, and cost-effective. Genomic, proteomic, transcriptomic, and metabolomic technologies have increased the uniformity and predictability of plant breeding, decreasing both time and price while developing superior crops that are stress-resistant yet still have a high nutritional value. Omics has shed light on the molecular processes behind insect resistance to pesticides and plant tolerance to herbicides, allowing for more effective pest control. The use of omics research in agriculture has led to the identification of the genetic sequences controlling agronomic parameters including grain production, tolerance to biotic and abiotic stressors, etc. Abiotic factors, such as low or high temperatures, water shortages or surpluses, high salinity, and UV radiation, are harmful to plant growth and development, which results in a significant loss in agricultural output around the globe. It is essential to develop crop types that are resistant to abiotic factors to preserve food security and safety in the years to come.

Key words : *Omics, abiotic stressors, pearl millet, dna marker, gene.*

Introduction

Agricultural species offer food, fiber, biopharmaceuticals, and models for biomedical research (McCarthy *et al*; 2006). A wide variety of environmental stress is experienced by plants, which lowers and restricts the yield of agricultural products. Plants experience two kinds of environmental stress, which are classified as (a) Abiotic stress and (b) Biological stress or Biotic stress. Abiotic factors that negatively affect crop and other plant growth, development, yield, and seed quality include drought (water stress), excessive watering (waterlogging), temperatures (cold, frost, and heat), salt, and mineral toxicity. Future experts believe that when fresh water becomes more scarce, abiotic stress factors will become more intense. To maintain food security and safety in the upcoming years, it is crucial to create crop varieties that are resistant to abiotic stressors (Gull *et al*; 2019).

Agriculture must produce more food to keep up with population growth as the world's population is expanding quickly. Crop breeding is a sustainable method of boosting yield and yield stability without raising the use of pesticides and fertilizers. The advantage of increasing crop improvement is provided by recent development in genomics and bioinformatics (Hu *et al*; 2018). With the increasing importance of information for decision-making and the technological

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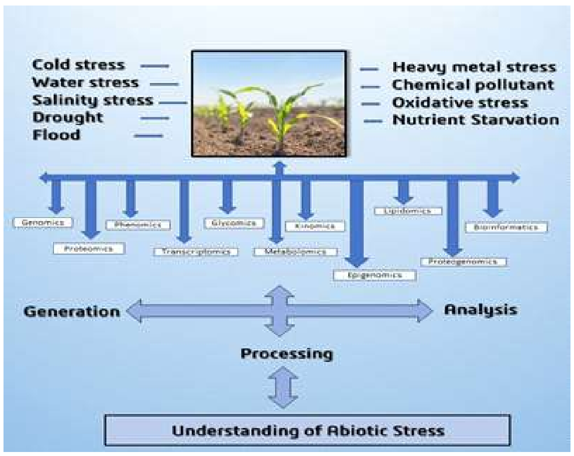
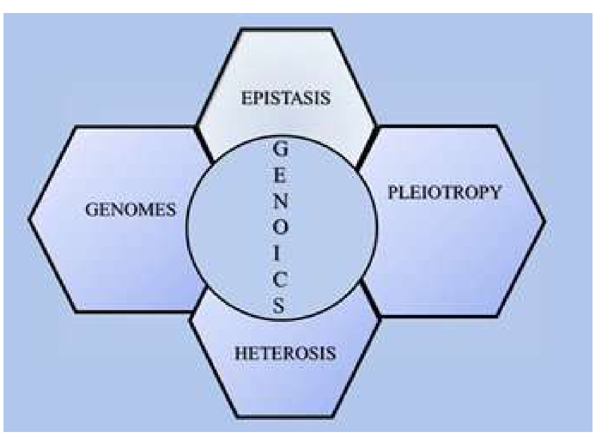
options that can empower the farmer through Information and Communication Technologies (ICT), bioinformatics has the potential to significantly transform the agricultural sector (Kumar *et al*; 2018). Almost every research institution has a dry lab infrastructure, and agriculture bioinformatics is in the process of expanding its technological advancements. Examples include high-end computing systems, high-speed internet for transferring the majority of genome sequences to major research institutions and laboratories, etc.

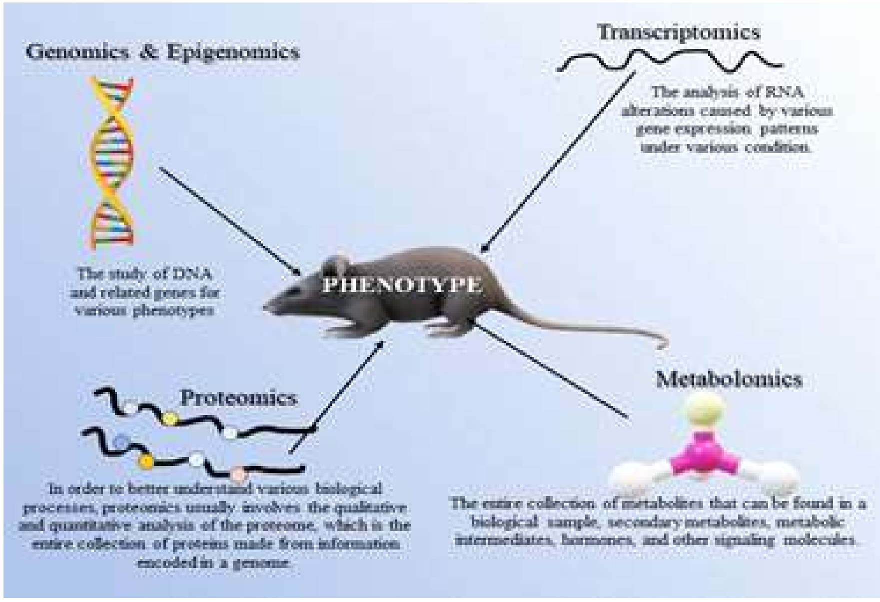


The field of agricultural bioinformatics does not confine itself to basic biology alone but also encourages the interpretation of genomic data with the assistance of other fields (Lata *et al*; 2015). The term "omics" refers to a biological scientific field of research that ends in "omics," such as genomics, transcriptomics, proteomics, metabolomics, etc. When referring to the subject to study, such as the genome, proteome, transcriptome, or metabolome, the suffix -ome is used. The study of the structure, function, evolution, and mapping of genomes is known as **Genomics**, and its goal is to characterize and quantify the genes that control the production of proteins with the help of enzymes and messenger molecules.



The collection of all messenger RNA molecules in one cell, tissue, or organism is known as the **Transcriptome,** it includes the molecular identities, structure, function, and dynamics of a cell, tissue, or organism, as well as the quantity or concentration of each RNA molecule. The total number of proteins present in a cell, tissue, or organism is referred to as its proteome. **Proteomics** is known to study protein biochemical characteristics, functional roles, and changes in their quantities, alteration, and structural features during development and in reaction to both internal and external stimulations. The collection of all metabolites as a by-product of a cellular process found in a biological cell, tissue, organ, or organism is known as the **Metabolome**. The field of science known as metabolomics investigates all metabolite-related chemical reactions. **Metabolomics**, or the study of all small-molecule metabolite profiles, is more precisely the study of chemical fingerprints that particular cellular processes create during their activity. Identifying, describing, and quantifying all biological molecules involved in the structure, function, and dynamics of a cell, tissue, or organism is the overall goal of omics science (Vailati *et al;* 2017). Studying genetic material in collaboration with bioinformatics can produce appropriate results that speed up the development of new varieties (Yadav *et al*; 2015). The genomes of many agricultural species and the diseases that affect them have been sequenced, and more is being done. McCarthy *et al*; 2006).

Recent research has concentrated on identifying the molecular response of plants to abiotic stressors since responses are controlled by the plant genome. Model plants like Arabidopsis and rice were the focus of studies on plant stress responses till today, whereas orphan crops like millets trailed far behind (Lata *et al*; 2015). An essential C4 cereal species with a remarkable potential for survival in harsh climates is the **Pearl millet**. It is an important source of food for people living in arid and semiarid areas of southeast Asia and Africa (Jha *et al*; 2021). Drought is the biggest obstacle to the cultivation of pearl millet since it is mostly grown in rainfed production systems in arid and semiarid locations. In particular production conditions, salt and high temperatures are also becoming new obstacles in the growth of pearl millet. Pearl millet genetic linkage maps are available, and genomic areas influencing yield in drought-prone locations have been discovered, paving the way for marker-assisted selection. To utilize them in breeding



Transcriptomic studies on Pearl millet

Strategy	Nature of study	Reference
Subtracted cDNA library	Identification of differentially regulated transcripts from a drought-tolerant parental line under salinity, drought, and cold stresses	Mishra *et al*; 2007
RNA isolation, library construction, and sequencing	When growing pearl millet under salt stress, DEGs encoding transcription factors, ion transporters, and metabolic pathway regulators are incredibly helpful.	Shinde *et al*; 2018
Small RNA sequencing identified micro RNAs in pearl millet.	Identified 81 conserved and 14 novel miRNAs that were differentially regulated by the salinity stress.	Shinde *et al*; 2020
Chromosome positioning, gene structure, and gene duplication analysis for PgNACs	151 NAC transcription factor genes (PgNACs) in the pearl millet genome. Genes showed diverse salt- and drought-responsive expression patterns in roots and leaves that are potentially involved in regulating abiotic stress tolerance in pearl millet.	Dudhate *et al*; 2021
RNA extraction, library preparation, and sequencing	ICMB 843 is relatively more tolerant to drought than ICMB 863 at the seedling stage. RNA-Seq analysis showed that ICMB 843 activated more drought-responsive genes than ICMB 863. Genes related to photosynthesis, plant hormone signal transduction, and MAPK signaling pathways were induced by drought in pearl millet	Dudhate *et al*; 2018
Identification and sequence analysis of MYB TFs in pearl millet	Functional characterization of MYB family members of pearl millet and genetic improvement of crop plants.	Chanwala *et al*; 2022
Biochemical and Molecular Analysis	Presence of substantial genetic diversity among the 33 genotypes of pearl millet for salinity stress tolerance at the early vegetative stage.	Jha *et al*; 2022
Genetic linkage map reported in pearl millet		
DNA marker		
99 polymorphic EST-SSR markers	116 EST-SSRs, 53 genomic SSRs, and 2 STS markers mapped on one or more of the four F7 RIP	Rajaram *et al*; 2013
75 gene-based markers (SNP and CISP) 574 polymorphic DArT markers 17EST-SSR markers	A genetic linkage map using 258 DArTs and 63 SSRs spanning 1148cM	Sehgal *et al*; 2012 Supriya *et al*; 2011
44 SSRs derived from a genomic library	A genetic map using 353 RFLP and 65 SSRs A genetic map, with 61 RFLP and 30 SSR loci spanning 476 cM	Qi *et al*; 2004 Yadav *et al*; 2004

programs, the germplasm and breeding material with a higher level of resistance to high temperatures and salt have been found (Yadav *et al*; 2012). Issues about the function of stress-sensitive genes, regulatory networks, and the related metabolic processes cannot be answered only by it. As a result, it is essential to incorporate more quantitative and qualitative evaluations of gene expression products at the transcriptomic, proteomic, and metabolomic levels, as well as bioinformatics and systems biology methods, which will further enable a more focused use of marker-assisted selection (MAS) and transgenic technologies (Dita *et al*; 2006). To create better cultivars, genomics as a whole requires the synthesis of molecular markers and the alteration of quantitative trait loci (QTLs) using MAS. By eliminating the time and labor-intensive direct screening of germplasm cultivated in fields and greenhouses, these genomic resources simplify breeding techniques for agricultural development initiatives. In investigations of comparative mapping and synteny in agricultural plants, genetic maps, and molecular markers are also helpful. E.g., one of the research has demonstrated the synteny between the chromosomes of pearl millet, foxtail millet, and other grasses (Rajaram *et al*; 2013). Pearl Millet comprises a significant collection of genetic and genomic materials, including a variety of DNA-based molecular markers like RFLP (Liu *et al*; 1994), AFLP (Allouis *et al*; 2001), STS (Devos *et al*; 1995), SSR (Qi *et al*; 2004), SNP and CISP markers (Sehgal *et al*; 2012).

Using segregating populations produced from two independent crossings between H 77/833-2 and PRLT 2/89-33, as well as ICMB 841 and 863B, a significant QTL for terminal drought tolerance in pearl millet was found and mapped to linkage group 2 (LG 2) (Serraj *et al*; 2005), Bidinger *et al*; (2007), Bidinger *et al*; 2005).

Due to accessible high throughput genotyping drought-responsive growing interest among researchers in replicating success with omics in other well-studied cereal signaling rice and wheat, studies employing omics technologies for drought tolerance in pearl millet have gained some traction in the past ten years. The publication of the draft genome sequence of pearl millet gave research efforts a significant boost by making a mass of genetic information available for enhancing abiotic stress tolerance (Varshney *et al*; 2017). Pearl millet transformation by the biolistic method of gene delivery is reported by Taylor *et al*; 1991, who employed the plasmid pMON8678 for transformation, and published the first report on pearl millet transformation by particle bombardment. Later, several groups reported on the biolistic transformation of this crop with various target tissues and transgenics that were developed to fight off fungal pathogens (Ceasar *et al*; 2009). However, so far, there has been no report on pearl millet that has been genetically modified and enhanced in its resistance to abiotic stress. Shoot apices have been used by Agrobacterium to alter pearl millet reported (Jha *et al*; 2011and Lata *et al*; 2015).

Understanding the abiotic stress tolerance mechanism in pearl millet, which can then be applied for MAS or traditional breeding, would need a coordinated effort including all omics. The mapping of abiotic stress QTLs in pearl millet crops is still in the progressive stages. Researchers worldwide must make severe efforts in this direction to understand the biological networks operating in this crop which is nutritionally and economically significant, as there has not been much work done using systems biology approaches for deciphering regulatory networks in the pearl millet crop (Lata *et al*; 2015).

Conclusions

Omics approaches have shown to be the simplest and most effective bioinformatics applications for enhancing abiotic stress tolerance in Pearl millet, which lacks the requisite resources for conventional plant breeding. The molecular groundwork of the stress response must be understood, nevertheless for omics to be employed for abiotic stress tolerance. Using current and prospective high-throughput sequencing technologies, researchers may access a variety of sequencing applications, such as the discovery of molecular markers, short RNAs, and SNPs. By merging NGS techniques with genome-wide expression profiling studies, problems caused by large genomes, particularly those present in millets, can be resolved. Research on transcriptomics and genomes still outpaces that on proteomics and metabolomics. Omics will not only greatly aid in the discovery of the genes, proteins, and metabolites involved in several molecular and signaling networks, but it will also increase our understanding of the molecular underpinnings of this crop and its resistance to abiotic stress. It is necessary to carry out this sort of research in Pearl millet on a large scale to overcome abiotic stress.

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Chapter 6

Dimensions of Food Security and Climate Change

Harsimran Kaur and Ramandeep Singh
School of Business Studies, Punjab Agricultural University, Ludhiana, Punjab
Email : harsimrankaur447@gmail.com

Abstract

Our energy comes from food, and having insufficient access to it has numerous negative effects on our health. Food security is the state of having physical, social, and economic access to enough, safe, and nutritious food that satisfies one's dietary needs and food choices in order to lead an active and well-balanced life. In accordance with varying levels, four aspects of food security have been recognised. (i) National Availability, (ii) Home Accessibility, (iii) Individual Utilization, (iv) Stability. This factor of time that influences all levels may be evaluated. For complete food security, all four of these components must remain intact. In many fields, food security is seen as a causal, linked pathway from production to consumption, through distribution to processing, rather than as four "pillars." The relationship between food security and food insecurity is dynamic, reciprocal, and time-dependent, and the outcome is influenced by how well coping mechanisms interact with the challenges of food insufficiency. One of the most urgent issues facing humanity in this era is climate change. It is commonly acknowledged that climate change will have significant effects on the food security. In this context, we can examine the connection between food security and climate change. It focuses on how climate change may affect the four aspects of food security (access to food, availability of food, usage of food, and stability. All nations in the world are very concerned about climate change and its effects since they have the ability to endanger life on the earth. Consequently, considerable attempts have been made here only to research how climate change is affecting India's food security, particularly with regard to the agro-climatic zones. The expectations of food security in India under the oncoming climate change depends upon factors i.e., reduced food system vulnerability to climate change, other worldwide environmental changes etc.

Key words : *Food security, food insecurity, dimensions of food security, climate change.*

Introduction

Food is regarded as an essential component of life, whether it be for humans or other living things. It is necessary to fulfil this basic need in order to maintain good health, carry out one's responsibilities effectively, recover from illness, promote proper child growth and development, and survive. The issue of food is seen as being of utmost importance in articles, periodicals, dialogues, and ads.

The World Food Summit in 1996 defined food security as a situation "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". At the World Summit of Food Security in 2009, this definition was reconfirmed, and the concept was extended and specified by adding that the "four pillars of food security are availability, access, utilization, and stability" and stated that "the nutritional dimension is

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integral to the concept". The strength of this definition is its comprehensiveness and imperative for "concerted actions at all levels" (that are "individual, household, national, regional, and global levels") and "coordinated efforts and shared responsibilities" across institutions, societies, and economies to tackle food insecurity effectively (FAO 1996, par. 1). Furthermore, poverty is regarded as the major obstacle to achieve food security at the household level so that "poverty eradication is essential to improve access to food" (FAO 1996, par. 2).

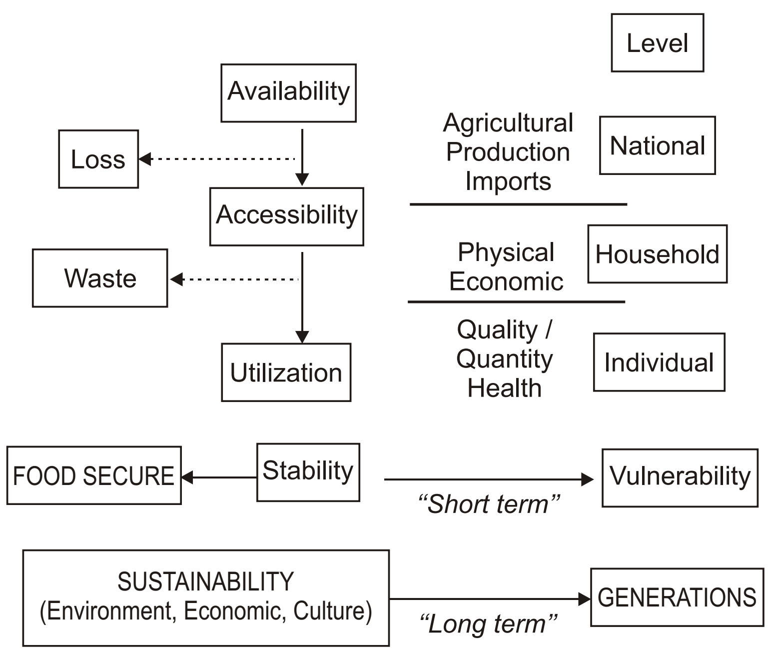
According to the Food and Agriculture Organisation of the United Nations (FAO, 2009), "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". The discussion of sustainable development has also focused heavily on the idea of food security (FS). In fact, the first Millennium Development Goal (MDG) aimed to "Eradicate extreme poverty and hunger" (United Nations, 2015a). More recently, from 2016 on, the second Sustainable Development Goal (SDG) "Zero Hunger" aims to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" (United Nations, 2015b).

Dimensions of food security

According to the concept, there are four aspects of food security which have been identified. (FAO, 2008). 1. Availability: The food can be produced domestically or imported from abroad which is available to the consumers. 2. Accessibility: The food can easily reach to the consumers with the help of proper transportation facilities and also the consumers have enough money for purchase. Sociocultural accessibility is added to such physical and financial accessibility to guarantee that the food is culturally acceptable and that social safety safeguards are present to help the less fortunate. 3. Utilization: For a person to live a healthy and complete life and reach their potential, there must be able to eat a suitable amount of food both quantity and quality. Sufficient amount of water and sanitation are also necessary at this level since food and water must be secure and clean. To be able to digest and use the food they eat, a person must also be physically healthy. 4. Stability: it deals with capacity of the country, community or person to tolerate disturbances to the food chain system, whether they are brought on by natural disasters (earthquakes, climate), or those that are produced by man-made disasters, is covered under the fourth domain of stability (wars, economic crises). So, it is clear that there are various levels of food security.

In the 2009 World Summit definition on Food Security, the Summit used for the first time the phrase "four pillars of food security", representing the four dimensions, namely, availability, accessibility, utilization and stability, of food security (FAO, 2009).

Food insecurity is a sign of the global food system's failure, which is being impacted by an unexpected combination of factors such as climate change. The definition of FINS is "whenever the availability of nutritionally adequate and safe foods, or the ability to acquire acceptable foods in socially acceptable ways, is limited or uncertain". Furthermore,



The concept of Food Security, (Wen Penga B. and Elliot M. Berryc)

FAO (2016) puts that "Through its impacts on agriculture, climate change will have negative effects on food security in all of its dimensions. While food security will be affected through other channels – for example, by extreme weather events that reduce urban dwellers' incomes and thus access to food – agriculture is a key channel through which climate change affects food security". The natural resources such as water and land which is used in agricultural production are influenced by climate change. Climate change (CC), which affects both agriculture and food security, is one of the most urgent problems facing humanity. Moreover, the SDG 13 "Climate action" aims to "Take urgent action to combat climate change and its impacts" (United Nations, 2015b). Additionally, Climate Change (CC) poses a risk to achieving other SDGs, including SDG2 "Zero hunger". In this framework, we try to examine the relationship between the climate change and food security. It specifically examines how CC affects the four aspects of food security.

India possesses multiple reasons to be worried about climate change, as the bulk of the population relies on industries that are highly vulnerable to climate change, such as agriculture, forestry, and fishing. If the current issue of food security in our nation is not resolved soon, climate change will make it worse. Given the changing environment, it will be harder to provide food security in countries such as India, where an estimated one-third of the population lives in absolute poverty and half of all children suffer from some form of malnutrition (Dev and Sharma, 2010). Given the numerous components involved in this phenomenon, it is highly complex to analyse how climate change may affect the Indian agricultural sector. In order to thoroughly explore the influence of climate change on food security, we have selected the four components of food security and discussed how each is affected by it in the context of India.

Climate change and food production

In order to assess whether specific climate-induced changes in biochemical processes will have a positive, negative, or neutral impact on agricultural production, food supply, and livelihoods based on agriculture, it is important to consider the characteristics of the agroecosystem where these changes are occurring. Where there is more atmospheric CO_2 to boost plant development, the greenhouse fertilisation effect will have local beneficial benefits. With a yield rise of 10 to 25%, this is anticipated to happen mostly in temperate zones. These consequences are unlikely to have an impact on predictions of the global food supply (Tubiello et al., 2007). But because of the predominant tropical climate in India, greenhouse fertilisation there is likely to have negative effects. Depending on where you are, you will experience the effects of the mean temperature increase differently. For instance, a few days of temperatures that are too high or too low might harm the harvests of fruit trees and grain crops. Currently, there are 500 weather-related disasters annually on average, up from 120 in the 1980s; during the same time span, the occurrence of floods has increased six-fold (Oxfam 2007). Long-term effects on the sustainability of the existing and future food supply in India include increased storm severity and frequency, altered hydrological cycles, and precipitation variability. Water availability restrictions are a developing issue that the issue of climate change will make worse. Food production and people's access to food will be affected by water resource conflicts in conflict zones (Gleick, 1993). Even now, there are many interstate and intrastate water disputes in India, but as a result of climate change, there will be an even greater shortage of water and a greater intensity of these types of conflicts in the future. All of these elements will worsen the food availability issue.

Climate change anf food access

Food is distributed using market-based distribution channels and non-market based distribution channels. When determining affordability, factors are taken into account that affect whether individuals will have access to enough food through marketplaces. Furthermore, (FAO,2008) states that "these factors include income-generating capacity, amount of remuneration received for products and goods sold or labor and services rendered and the ratio of the cost of a minimum daily food basket to the average daily income". Production for personal consumption, home food preparation and distribution customs, and public food distribution programmes are examples of non-market systems. India has a rural population that makes up about 70% of the total. Climate change effects on food products may decrease availability in rural India, where individuals grow a large fraction over their own food, to the point that household distribution decisions must be made. A family may decide to cut back the on the volume of food that is consumed on daily basis by all members of the household equally, or they may decide to allot food preferentially to specific members, typically the physically fit male adults who are assumed to need it the most in order to maintain their health or continue supporting the family. Due to the effects of climate change, low-income non-farming households with earnings below the poverty line will have comparable options in both rural and urban locations. As a result, metropolitan areas are anticipated to experience an increase in the importance of allocation problems caused by climate change. Because the majority of the stable food they need still needs to be delivered from rural areas, urban agriculture has a limited ability to improve the wellbeing of poor people in India. When this ratio falls below a predetermined threshold, it indicates that food is affordable and people are not in poverty; when it exceeds the established threshold, food is not affordable and people are struggling to get enough to eat. This ratio is used by many countries as a measure of poverty (World Bank Poverty Net, 2008).

Climate change and food utilization

Because persons who are unable to meet all of their nutritional needs typically follow diets that do not include nourishing dietary grains, food insecurity is frequently linked to malnutrition. Nutritional status may be negatively impacted by decreases in the accessibility of mild foods and restrictions on small-scale agricultural production due to a lack of water or manpower brought on by climate change. Generally speaking, however, the primary consequences of climate change on nutrition are likely to be felt indirectly through its effects on income and capacity to acquire in order to vary their basic needs such as food. In India, climate change will lead to the emergence of new patterns of pests and illnesses that will impact plants, animals, and people. This will increase the danger to human health, food security, and food safety. The food chain and people's physiological ability to obtain essential nutrients from the foods they eat could be affected by an increase in the prevalence of water-borne illness in food-prone regions like the U.P, Bengal, Orissa, Bihar, Andhra Pradesh, and Maharashtra, among others; by changes in the quantity for pests and diseases that respond to climate change; and by the emergence of new diseases. These put crops, cattle, fish, and people at risk in new ways that they haven't yet adapted to. Additionally, they will increase the demand on caretakers in the house. Flooding driven on by sea level rise may expose more people in India's coastal districts to vector- and water-borne diseases. Numerous factors could threaten the safety of food. If more money is n't invested in refrigerating and cooling perishable items to extend their shelf life, rising temperatures could lead to a decline in food quality.

Climate change and food system stability

Numerous crops have yearly cycles and yields that change in response to climatic variability, particularly variations in temperature and rainfall. When the production process is dependent on the weather, it is challenging to guarantee the consistency of the food supply. Food stability is particularly at risk from droughts and floods, which can result in both long-term and short-term food insecurity. India, as we all know, is a nation that is more vulnerable to drought and flooding. As a result of climate change, both are predicted to become more common, more severe, and less predictable in India. 70% of India's population lives in rural areas that rely mostly on rain-fed agriculture and are therefore dependent on the local food supply. The Sheer unpredictability of the local food system is expected to be made worse by changes in the quantity and timing of rainfall over the course of a season and by an increase in weather variability. The frequency and severity of food emergencies, for which the global food system is ill-prepared, are anticipated to increase as a result of increasing supply instability caused by the effects of climate change. There are many ways that climate change could make a conflict worse, but it's important to portray the connections between the two with caution. Increasingly frequent droughts may drive people to relocate, which could lead to conflict over the availability of resources in the receiving region. Conflict can also be sparked by a lack of resources, and this could be a result of environmental change on a global scale.

Conclusion

This study provides the analysis of various connections between food security and climate change. In India, there is need to adopt the sustainable agricultural practices. Better water resource management is a key component of sustainable agriculture. In India, more emphasis on public health was not taken into consideration when the initial National Action Plan for Climate Change (NAPCC) was created. Currently, the Ministry of Health is developing a National Mission for Health within the purview of NAPCC, but considering the intimate connection between climate change, infectious diseases, and food intake, public spending on health needs to be significantly increased. In order to achieve food security in the face of climate change, it is imperative that the lives of the poor and food insecure are improved. This will allow them to not only escape poverty and hunger but also to endure, recover from, and adapt to the climate threats to which they are exposed. The majority of India's disaster management plans are ineffective, transient, and badly thought out. Disaster relief must be viewed from a long-term perspective by the government. Furthermore, long-term undernutrition prevention programmes must be established in disaster-affected areas due to the negative effects of natural disasters on child nutrition.

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Chapter 7

Morphometric and Land Use/Land Cover Analysis of Lower Himalayan Sub-Watershed Using Remote Sensing and Geographical Information System Techniques

P.L. Bhutia[1,2*], Saswat K. Kar[2], Sharmistha Pal[3], O.P.S. Khola[3], K.G. Bhutia[4], Rakesh Kumar[5] and Azeze Seyie[1]
[1]*ICAR-Research Complex for NEH Region, Medziphema-797106, Nagaland*
[2]*ICAR-Indian Institute of Soil and Water Conservation, 218-Kaulagarh Road, Dehradun-248195, UK*
[3]*ICAR-Indian Institute of Soil and Water Conservation, Sector 27A, Madhya Marg-160019, Chandigarh*
[4]*Rain Forest Research Institute, Jorhat-785001, Assam*
[5]*Rani Lakshmi Bai Central Agricultural University, Jhansi-284003, Uttar Pradesh*
**Email : pempadenzongpa66@gmail.com*

Abstract

The land use/ land cover (LU/LC) and morphometric assessments are vital for better scientific planning and management of the resources present in the area. This study shows the use of remote sensing (RS) and Geographical Information System (GIS) to examine the LU/LC classification and obtain different morphometric parameters of the sub-watershed in the Indian Terai Arc Landscape. LU/LC classification of the investigated area indicates that most of the area in the sub-watershed is covered by forest. However, agricultural lands are dominated at the lower elevational zones having near flat to gentle slopes. The morphometric analysis of the study area confirms that the sub-watershed is nearly circular in shape, having a dendritic drainage network with a very coarse drainage texture. The findings of the present study can be used for restorative programmes including the establishment of site-specific soil and water conservation measures such as staggered trench, check dam, spillway, etc.

Key words : *ALOS-DEM data, GIS, land use/land cover, morphometry, sentinel 2 image*

Introduction

GIS and RS techniques based on satellite imageries are commonly used in the present time for analysis of data such as morphometry, and land use/land cover (LU/LC) pertaining to their high efficiency, less time consumption and suitability for wide spatial planning. The usage of computers has made GIS capable of handling not only enormous datasets but also a variety of complicated problems in addition to making data retrieval and querying easier.

The land use pattern and the morphometry of any landscape is a manifestations of the intricate physical processes taking place on the earth's surface. Natural resource management and planning activities at the watershed level make a viable option as all the resources located in the watershed are interlinked physically, socially and economically than those outside the watershed area (Marh,1998). Information on geomorphology, land use, and land cover status must be reliable and available at a suitable time in order to have improved scientific planning and

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management of the resources in the watershed area. The present study area is one of the significant sub-watershed in Nandhaur wildlife sanctuary which is a part of TAL, harbouring many flagship wildlife species and a large human population. The watershed is facing rapid vegetation fragmentation and degradation as a result of intense anthropogenic pressures like excessive riverbed mining and overutilization of forest resources (Verma, 2011). This interference has also deteriorated the habitat of wildlife and hence increased the incidence of human-wildlife conflicts in the area. Here in the watershed, the farming community is entirely dependent on income or services from natural resources. Information on LU/LC classification as well as morphometric parameters of the watershed is imperative for sustainable utilization of resources present there and to prevent further degradation of the watershed for healthy human-wildlife interactions. Hence, the present investigation was taken up to determine the morphometric parameters and LU/LC classification of the sub-watershed for efficient resource planning and management.

Study Area :

The sub-watershed of Nandhaur Wildlife Sanctuary (NWS) of Nainital district, Uttarakhand, India was selected for the study. The watershed lies between 28° 56' 13" to 29° 9'26" N Latitude and 79° 42' 42" to 80° 0' 40" E Longitude having an area of approximately 425.02 sq km (Fig.-1).

Fig.-1 : Study area.

Morphometric Parameters

Processing of the DEM : The processing of ALOS-DEM data having a 30-meter spatial resolution was done using ArcGIS 10.4 software. The DEM was projected to UTM coordinates in WGS 1984, Zone 44 North. The fill, flow accumulation, flow direction, raster calculator, flow length, stream order, and watershed boundary have been generated using the hydrology tool under the spatial analyst tool and also slope and aspect maps have been created using the surface tool under the spatial analyst tool in ArcGIS-10.4 software. Different formulas were adopted for the computation of various morphometric parameters of the investigated sub-watershed (Horton, 1932; Horton, 1945; Miller, 1953; Schumm, 1956; Strahler, 1964).

LU/LC Classification

Processing of Sentinel 2 Image : The Sentinel 2 satellite imageries taken during April 2018 were freely downloaded from the Copernicus Open Access Hub on 3rd December 2018. Downloaded images are Level 1C product, where per pixel radiometric measurements are given in Top of Atmosphere reflectance. The level 1C product was corrected for radiometric and geometric discrepancies but not for atmospheric. Atmospheric correction of imagery was carried out by using the external plugin Sen2Cor-02.05.05-win64 of SNAP software. After the atmospheric corrections, all 12 remaining bands of the corrected Level 2A imagery was resampled to 20 m spatial resolution and reprojected to WGS 84 by using SNAP software.

Random Forest Classification : After the selection of the imagery, a few training sites were assigned to each LU/LC type of the selected sub-watershed. Thereafter, random forest classification under supervised classification in SNAP software was utilized to classify different LU/LC unit. The classified map was then imported to ArcMap (version 10.4). A shape file of the study area was made and the area of interest was clipped off from the classified image

Morphometric Analysis of the Selected Sub-watershed :

Watershed (Area and Perimeter) : The selected sub-watershed is near circular in shape covering an area of about 425.02 sq. km. The perimeter of the sub-watershed is about 110.70 km with a maximum length of watershed i.e., 28.44 km.

Stream order : The present sub-watershed has a dendritic drainage pattern indicating that that the study area has homogenous subsurface strata (Fig. 2). The existing streams in the sub-watershed are mostly parallel to each other. The sub-watershed is having upto 4thorder drainage system (Table-1).

Stream Number : A total of 147 streams are identified in the sub-watershed, 72 of which are I order, 53 are II order, 18 are III order, and 4 are IV order streams.The data present in Table 1 indicates that the stream frequency decreaseswith the concurrent increase in stream order suggesting the flow of streams from a higher altitude and lithological variation (Table-1).

Stream Length : Stream length and their ratio are the main parameters for studying the hydrological attributes (discharge) of the river basin and also the permeability of the underlying rock in the basin. Longer streams typically indicate flat areas with lower slopes, while shorter streams are more common in mountainous areas with greater slopes.The average length of I order, II order, III order and IV order streams were 2.10 km, 1.64 km, 2.01 km, and 2.34 km, respectively whereas, the total length of I order, II order, III order and IV order streams were 151.41 km, 86.73 km, 36.17 km and 9.36 km, respectively with sum total length of all the stream of 283.78 km and average streams length of 1.93 km (Table-1).

Stream Length Ratio : The stream length ratio of the study area increased from 0.78 for II/I stream order to 1.23 for III/II stream order and then decreased to 1.16 in IV/III stream order (Table-1). This alteration

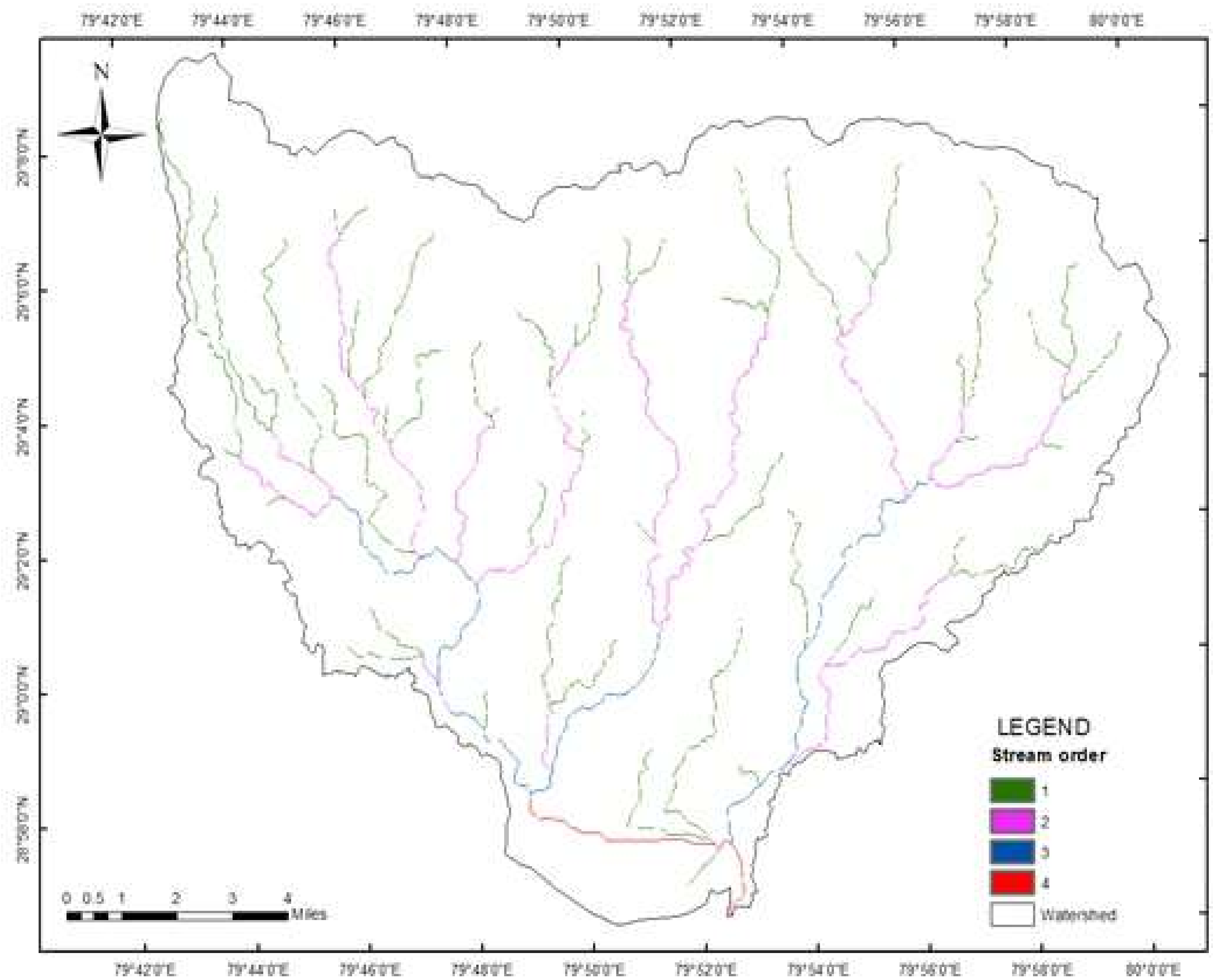

Fig.-2 : Drainage map showing stream order.

Table-1 : Morphometric parameters of the Sub-watershed.

Stream order	No. of streams	Bifurcation ratio	Mean Bifurcation ratio	Total length of streams (km)	Average length of streams (km)-order wise	Average length of stream segment (km)	Length ratio (RL)	Average stream length ratio
I	72	1.36	2.93	151.41	2.10	2.02	II/I (0.78)	1.06
II	53	2.94		86.73	1.64		III/II (1.23)	
III	18	4.5		36.17	2.01		IV/III (1.16)	
IV	4			9.36	2.34			
Total	147			283.78				

Table-2 : Different morphological parameters of the Sub-watershed.

Drainage length (km)	Drainage density (km^{-1})	Stream frequency	Texture Ratio	Form factor	Elongation ratio	Length of overland flow
38.81	0.67	0.35	1.33	0.53	0.82	0.746

may be linked to topographic and slope variations, which shows the late youth stage of geomorphic development in the streams of the sub-watershed.

Bifurcation Ratio : The Bifurcation ratio plays an important role in drainage basin analysis and it is the principal parameter that helps in linking the hydrological regime of a watershed under topological and climatic conditions. It also helps in illustrating the shape and the run off behavior of the basin. In general, *Bifurcation ratio* ranges from '3.0 to 5.0' for basins in which geologic structure do not alter the drainage pattern (Strahler, 1964). The presence of irregularities like bifurcation ratio values are not being same from one order to its next order are the characteristics of geological and lithological development of a drainage basin.Lower bifurcation ratio values indicate a watershed that has seen fewer structural disturbances and where such disturbances have not altered the drainage pattern (Nag and Chakraborty, 2003). While, area having steeply dipping rock strata with narrow valleys confined between the ridges may have abnormally high bifurcation ratio.The $R_b$valueindicates the shape of the basin, wherein an elongated basin is likely to have a high R_b, while a basin with a circular shape is likely to have a low R_b. The bifurcation ratio varies from a minimum of 2 for flat or rolling drainage basins to 3 or 4 for mountainous drainage basins. The bifurcation ratio of the present watershed ranged from 1.36 to 4.5 and ifthe bifurcation ratio is 2.93 which indicates that the drainage pattern existing in the watershed are less disturbed by any structural disturbances and its shape is near circular (Table 1). The bifurcation ratio is highly correlated with drainage density which means a high bifurcation ratio denotes a high drainage density and it leads to a shorter duration to reach the outlet for discharge due to less time of concentration and having higher peak discharge and greater probability of flood.

Drainage Density : The drainage density gives an idea on the closeness of stream spacing, thereby provide an average stream length for the entire basin. Areas with impermeable subsurface material, mountainous relief, and sparse vegetation result in high drainage density. Conversely, areas with relatively resistant or permeable subsurface material, low relief, and abundant vegetation result in low drainage density (Nag, 1998). Smith (1950) categorised drainage density into five different textures. A drainage density of less than 2 suggests a very coarse drainage texture, 2 to 4 shows a moderate drainage texture, 4 to 6 indicates a medium drainage texture, 6 to 8 indicates a fine drainage texture, and greater than 8 indicates a very fine drainage texture). The overall drainage density of the study area was found to be 0.67 km/km^2, signifying very coarse drainage texture (Table 2). A low drainage density as in present case is very common in the region which are composed of highly resistant subsoil strata, dense vegetation and low relief.

Stream Frequency : The stream frequency of the study area basin wasreported to be 0.35 (Table-4), indicating permeable sub-surface material, dense vegetation and low relief for the present study area.

Texture Ratio : Drainage texture is classified into 5 different groups i.e., (<2) very coarse, (2 to 4) coarse, (4 to 6) moderate, (6 to 8) fine and (>8) very fine(Smith, 1950).In the present investigation, the texture ratio of the study area was found to be 1.33 indicating very coarse drainage texture (Table-2).

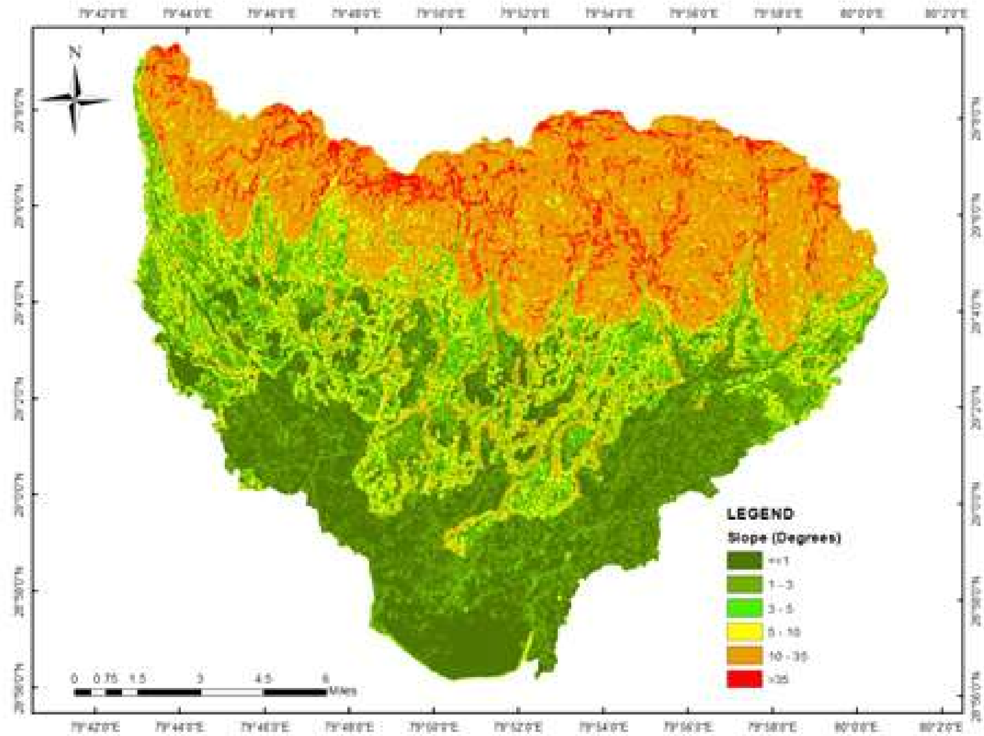

Fig.-3 : Slope map of the sub-watershed.

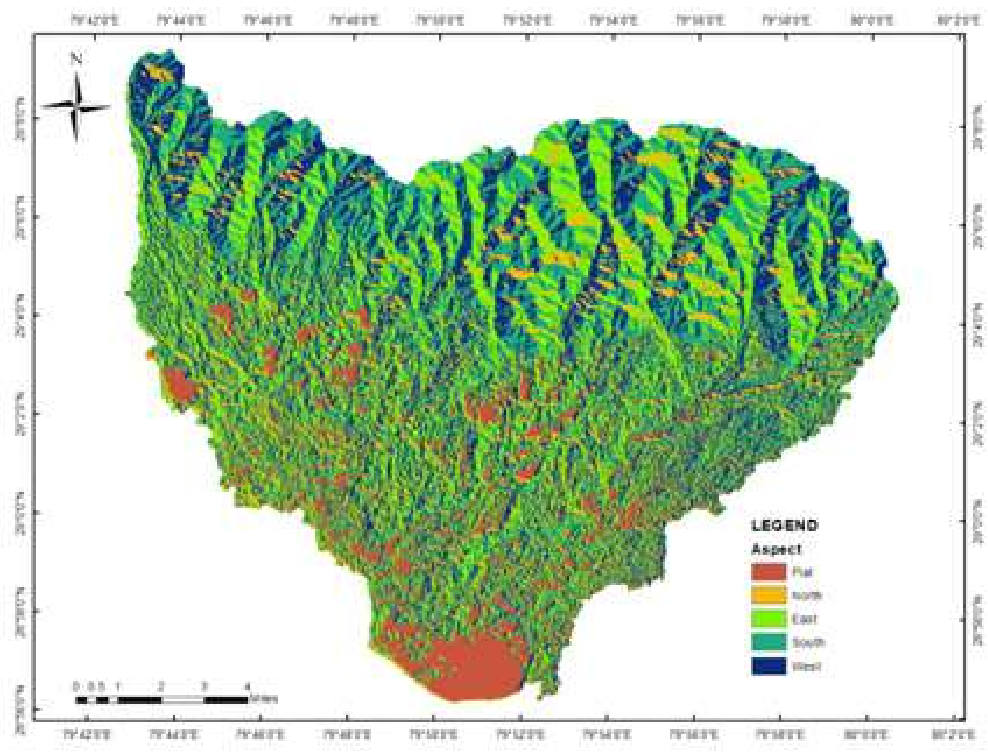

Fig.-4 : Aspect map of the sub-watershed.

Alluvial basins generally show very coarse to coarse drainage texture. Higher texture ratio value leads to more erosion.

Form Factor : A perfectly circular basin will always have a form factor value larger than 0.7854, while a basin with a smaller form factor value will be longer overall. High form factor basins have high peak flows that last for a lesser duration, whereas low form factor basins have lower peak flows that last for a longer time. In this study, sub-watershed has form

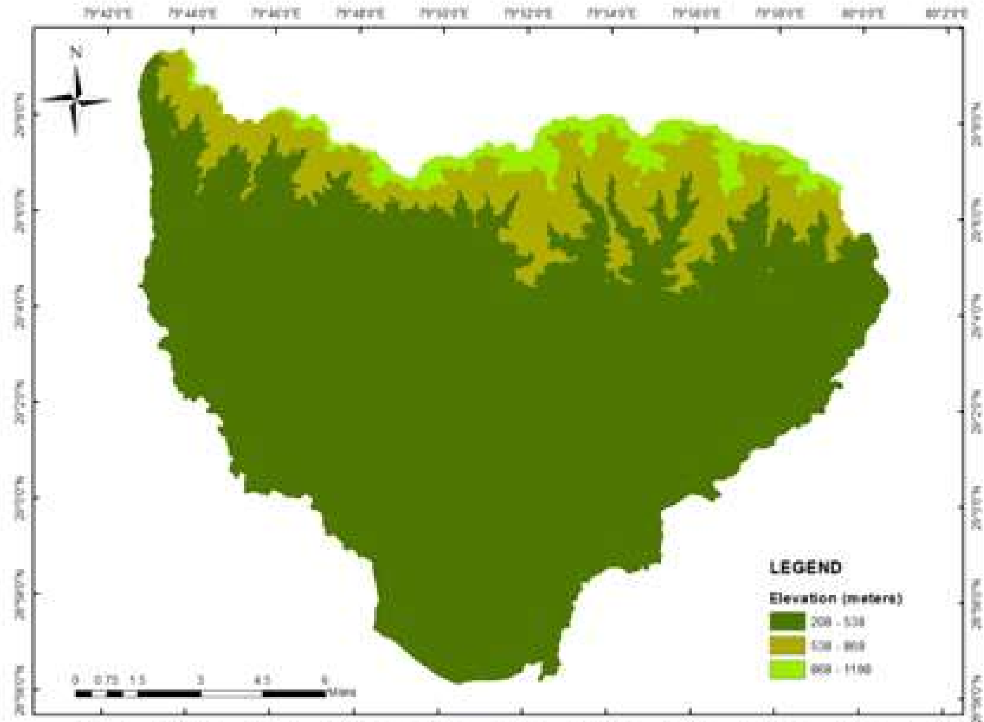

Fig.-5 : Elevation map of the sub-watershed.

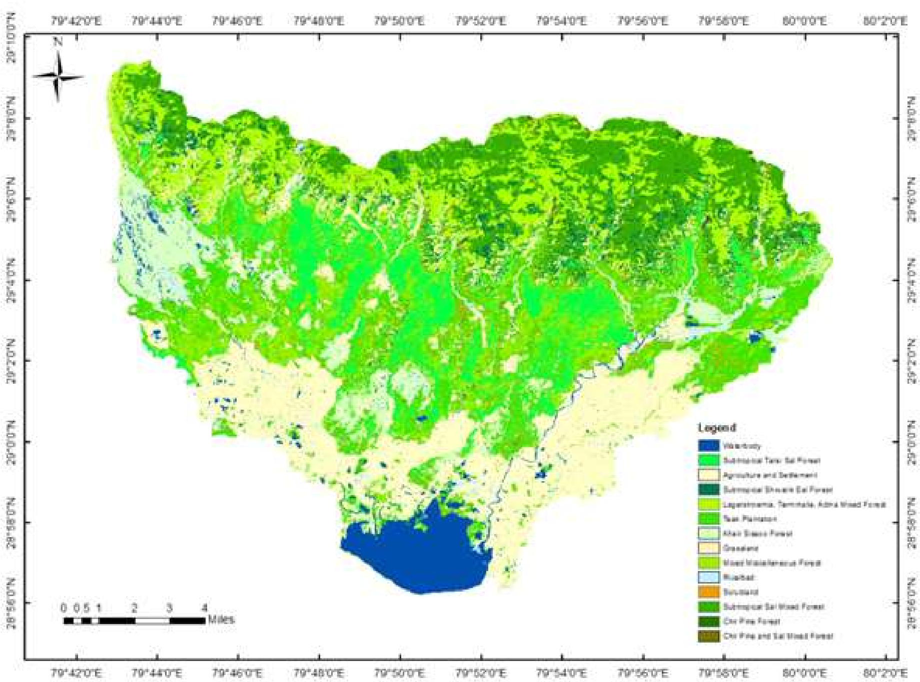

Fig.-6 : LU/LC map of the sub-watershed.

factor value of 0.53 (Table 2), indicating a medium form factor having medium peak flow for a longer duration and oval shaped drainage basin.

Circulatory Ratio : Circulatory ratio is the ratio of the drainage basin's surface area to the surface area of a circle which has perimeter same as the perimeter of the drainage basin. It indicates the shape of the basin. The length and frequency of streams, geological formations, land use and cover, climate, relief, and slope of the basin have an impact on the circulating ratio. The circulatory ratio value varies from 0 (line shape) to 1 (circle shape). In the present study, the circulatory ratio of the present sub-watershedisfound to be 0.44, indicating that the Sub-watershed is oval shape (Table-2).

Elongation Ratio **:** Elongation ratio is used as an index to mark the shape of the drainage basin. It depends on the variation in relief of the area. Elongation ratio values usually range from 0.6 to 1.0 throughout a broad range of climatic and geologic formations (Rudraiah *et al*., 2008). The region with very little relief will have an elongation ratio near 1.0, while values between 0.6 and 0.8 are typically indicative of high relief and a steep ground slope (Strahler, 1964). The elongation ratio values can be categorised into three groups (a) circular (>0.9); (b) oval (0.9–0.8); (c) elongated (<0.8). The elongation ratio in the present study was 0.82 (Table 2), indicating that the sub-watershed is havingan oval shape with low relief.

Length of overland Flow : The term "overland flow" describes the flow of precipitation that travels over the surface of the land leading to the stream channels. While, surface runoff refers to the channel flow that reaches the outlet of the watershed. The length of overland flow is calculated as half of the reciprocal of drainage density. The overland flow is significant in the smaller watershed whereas the runoff has a significant role in larger watersheds. The value of the length of over land flow of the study area was found to be around 0.746 km (Table-2).

Relief Ratio : The difference in altitude between the highest and lowest points in the basin is the total relief of that basin. The relief ratio is dimensionless and measures the overall steepness of the drainage basin. It is also considered as an indicator of the intensity of erosion processes operating at the basins slope. The relief ratio of the study area is 0.04 indicating low relief (Table-2).

Slope : Slopes of the watershed area was extracted from DEMs using the slope tool in Arc GIS (Fig.-3). The extracted slope was then reclassified into 6 classes i.e. $=<1^0$ (Near flat), 1^0-3^0(Gentle), 3^0-5^0 (Moderate), 5^0-10^0 (Steep), 10-35^0 (Very Steep) and>35^0 (Very Very Steep). The Slope of the watershed progressively increased as it moves towards the northern side from outlet. It was observed that most of the area of the sub-watershed falls under a very steep slope (33.09 %) followed by near flat (22.76 %), gentle slope (20.07 %), steep slope (11.61 %), moderate slope (8.39 %) and least in very very steep slope (4.08 %) indicating mixed topography of the sub-watershed. Areas under near flat and gentle slopes are considered an excellent category for ground water recharge purposesdue to the high infiltration capacity of the land.Watersheds with moderate slopeshaving slightly undulating topographyfalls under the good zone with the provision of some soil conservation measures like field bunding to reduce the erosive velocity of runoff.The moderate to steeper slopes having suitable rock base receiving high runoff are generally preferred as construction site for check dam, whereas for area having loose sub soil structure, vegetative measures along with temporary soil conservation structures may be recommended.

Aspect : The sub-watershed is segregated into five different aspects i.e. flat, north, south, east and west. The majority of the area (120.55 km^2) in the sub-watershed falls in southern aspects followed by the western aspect (111.27 km^2), eastern aspects (100.98 km^2), northern aspects (52.04 km^2), flat (40.17 km^2) constituting about 28.36%, 26.18%, 23.76%, 12.25% and 9.45% of the total area, respectively. This shows that the sub-watershed is having more hotter aspects than the cooler aspects indicating the depreciation of moisture content, soil formation and poor vegetation. Suitable soil and water conservations measures like bunding, trenching, gully control structures etc. may be suggested for successful establishment of vegetation (Fig.-4).

Elevation : The study area was classified into three elevational zones that is 208 – 538 m, 538 – 868 m and 868 – 1198 m (Fig. 5). Majority of the area (82.16 %) falls in lower elevation (208 m – 538 m) followed by medium elevation (538 m – 868 m) and high elevation (868 m – 1198m) range. As 80 % of the sub-watershed falls in the lower elevational zones where all the landuse/ land cover exists there.

LU/LC Classification : The sub-watershed area has been classified into thirteen LU/LC units*i.e.*, Waterbody, Agriculture and Settlement, Subtropical Shiwalik Sal Forest, Lagerstroemia, Terminalia, Adina Mixed Forest, Teak Plantation, Khair Sissoo Forest, Grassland, Mixed Miscellaneous Forest, Riverbed, Scrubland, Subtropical Sal Mixed Forest, Chir Pine Forest and Chir Pine and Sal Mixed Forest (Fig.-6). A perusal of data revealed that the Teak plantations occupied the largest area in the watershed covering about 15.16 % of the total study area followed by Subtropical Sal Mixed Forest (14.51%), Agriculture and Settlement (14.50%) and so on and least in Chir Pine and Sal Mixed Forest (0.27%). Agriculture and settlements are located in the lower elevational zones with flat to gentle slopes. The land is mainly used for growing wheat, sugarcane, rice, tomato and some seasonal vegetables. The ground truthing of the classified LU/LC was not done. Therefore, it is suggested to have a ground verification especially to validate different forest types before using the map.

Conservation measures based on morphometric analysis

The soil and water conservation structures should be constructed based on the requirement of the site, its condition, gully depth, slope, suitability for the area, and catchment area contributing runoff. The two main categories of soil conservation methods are (a) biological strategies and (b) mechanical treatments. Contour cultivation, mulching, strip cropping, afforestation, reforestation, and monitoring for overgrazing are examples of agronomical methods. Terracing, contour trenching, building terrace outlets, gully control structures, check dams, and stream bank stabilization are mechanical solutions for land management. For the present sub-watershed, at the end of the first-order stream, mostly perimeter bunds act as an effective tool for erosion control and slope stabilization, and also in some cases, the upper reach bund is also given. Specifically, the staggered trench contour plays an important role in resource conservation for forest areas. The middle reach and upper reach bunds are generally preferred for second to third-order streams. For higher order streams having much runoff, the water harvesting structures are constructed with suitable spillway arrangement for removal of excessive runoff from the storage structure to protect it from damage and overflow. In some cases, having high drop in elevation and runoff some pakka (permanent) structures are also constructed like, drop, drop inlet and chute spillway. The dropinlet is generally placed at the outlet of a gully, a chute spillway is placed at the beginning of the gully having a steep slope, and a drop spillway along the gully bed to control the further progress of the gully.

Conclusions

The information generated in the present study will be useful for a sustainable watershed development programme of the area, including the establishment of a suitable site specific soil and water conservation structures (check dam, staggered trench, percolationtank, chute spillway. RS and GIS-based techniques not only help analyze varied morphometric parameters and classify LU/LC of the landscape but also explore the relation between drainage morphometry and the characteristics of soils, landforms, and eroded lands. Hence, it is inferred from the present study that ALOS (DEM) and Sentinel 2 data, coupled with GIS techniques, proved to be a competent tools in morphometric and LU/LC analysis.

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Chapter 8

Sustainable Sugarcane Initiative (SSI) for Higher Yield in Sugarcane Cultivation

S. Thiruvarassan[1]*, M. Jayachandran[2], E. Jamuna[1], R. Kanjanarani[1] and V. Vijaya Geetha[3]
[1]*Oilseeds Research Station, Tindivanam, Tamil Nadu Agricultural University*
[2]*Sugarcane Research Station, Cuddalore, Tamil Nadu Agricultural University*
[3]*Vegetable Research Station, Palur, Tamil Nadu Agricultural University*
Corresponding Author Email : thiruvarassan@rediffmail.com

Sustainable Sugarcane Initiative is a method of sugarcane production which involves using less seeds, less water and optimum utilization of fertilizers and land to achieve more yields. Driven by farmers, SSI is an alternate to conventional seed, water and space intensive Sugarcane cultivation. In SSI method, single budded chips from the healthy mother canes are used for raising nursery. The procedure given below has to be followed for the selection of healthy buds :

Select healthy canes of 7 to 9 months old which have good internodes length (7 to 8 inches) and girth.

Observe and avoid canes with disease infestation like fungus growth, spots etc. Cut the required quantity of canes.

Remove buds from the selected canes using Bud Chipper. The Bud Chipper comprises a handle and a cutting blade fixed on a wooden plank.

Keep the cane on the plank and adjust it in such a way that a single bud is placed exactly below the cutting blade. When the handle is pressed, single bud chip comes off the cane.

Large number of buds (about 150/hr) can easily be chipped in a short period of time. The chipped buds treated with organic or chemical solutions.

Nursery

Young seedlings are raised in the nursery. It is better to establish a shade net shed for the purpose of nursery management. It is a fully covered structure meant to provide shade and create other favorable conditions like warm and wind free environment. For raising the nursery, take-well decomposed coco-pith. Fill half of each cone in the tray with coco-pith.

Place the buds flat or in a slightly slanting position in the cones of a tray. Do not press or push it hard. Ensure that the bud side faces up Cover the bud chips in trays completely with coco-pith.

After filling all the trays, place them one above the other and finally keep an empty tray upside down at the top. About 100 trays (4 sets, each consisting of 25 trays) are to be placed together and wrapped tightly with polythene sheets. Place small weights on the bundles and keep it for 5 to 8 days in the same position to create high temperature and humidity.

Take measures to control termites around the trays by drenching the soil with Chlorpyriphos 50 EC (5ml/l) and ensure that there are no weeds in and around the nursery area.

Care should be taken to avoid water, air or sunlight entering into the trays by tightly covering and keeping the bundles in shade net or preferably inside a room. Create artificial warmth through electric bulbs if the climate is too cold. This is the most crucial phase of the nursery management.

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Under proper conditions (especially, warm temperature) within 3 to 5 days, white roots will come out and shoots will also appear in next 2 to 3 days.

Either on the 5th or 8th day (based on the climatic conditions), all the trays with sprouted buds are to be removed from the polythene sheet and kept side by side in beds on the ground (see Annexure for the details on arrangement of trays) to facilitate watering and other nursery management practices.

Based on the moisture content of coco-pith, watering to the trays (seedlings) has to be initiated in the evenings for the next 15 days using rose cans. Shoots will start growing strong and leaves will start sprouting. After appearance of two leaves, application of water can be increased gradually depending on moisture level in trays.

During six leaf stage (20 days old seedling), grading of the plants has to be done. Stop giving water for a day to loosen the coco-pith in the trays, this enables easy lifting up of the young seedlings.

Plants of similar age (height) can be lifted up and placed in one tray. This way grading of plants according to their height is achieved and damaged or dead plants can be removed.

Main field preparation

The main field preparation in SSI method is similar to that of conventional method. Removal of residues Main land preparation for sugarcane starts with clearing the preceding crop residues. Stubbles are to be collected and removed from the field. All residues can be incorporated into soil by a rotavator. Tillage operations through tractor drawn implements are most ideal and quick. After one or two initial ploughings, soil must be allowed to weather for a week or two before going for further tillage operations. Tillage operations can be carried out using harrows or rotavator. The operations are to be repeated to make the soil bed free from clods, weeds and crop residues. After tillage operation, the field should be deep ploughed using a tractor. If the field is uneven, leveling has to be done using a tractor operated leveler. While leveling, a gentle slope can be maintained to facilitate easy movement of irrigation water.

Transplanting

The ideal age for transplanting the young seedlings from nursery to the main field is 25 to 35 days.

Stop giving water one day before transplanting. This will loosen the coco-pith in cones and help in easy lifting of seedlings for transplantation.

While transplanting to the main field, zigzag method of planting can be followed to utilize more space and achieve maximum tillers.

Plant to plant distance of 2 ft has to be maintained for easy sunlight penetration and profuse tillering.

For better access to sunlight, follow North-South direction of planting. However, slope of the field should also be taken into consideration.

Seedlings are to be planted in the moistened soil.

To moisten the soil, irrigate the field one or two days before transplanting. Similarly, irrigation should be given immediately after planting. The water will flow and fill the air gaps around the plant, if soil compaction is not proper.

It is important to irrigate the field with minimum quantity of water instead of flooding.

§After the establishment of plants, the mother shoot may be cut to get even tillers. Plant should be cut just one inch above the ground with a revolving scissor. This will ensure more number of tillers and millable canes per plant. It is better to try this practice in a smaller area initially and extend further based on the success rate.

Weeding

A weed-free environment is absolutely essential for efficient intake of nutrients. Deep ploughing and removal of perennial weeds. Hand weeding and mechanical weeding (30, 60 and 90 days after planting) is better for long term benefits. Appropriate other measures to control the weeds should be practiced to minimize the production loss.

Fertilizer application

Nutrient management in sugarcane cultivation is very essential for crop growth and the required quantity of nutrients based on the soil testing. If there is no facility for that, then NPK can be applied at the rate of 112 kg, 25 kg and 48 kg per acre, respectively through inorganic or organic methods.

Inorganic fertilizers like Urea, Super Phosphate, Muriate of Potash and Ammonium Sulphate are applied to achieve the above mentioned nutrient requirement.

Practicing appropriate cultivation practices like wider spacing, mulching and earthing up, the required quantity of NPK can be achieved by applying optimum or less quantity of these fertilizers.

The recommended quantity of fertilizers can be applied in 2 to 3 split doses for the efficient utilization by plants.

Further, by applying organic manures at the time of field preparation and incorporation of green manures into the soil, sufficient quantity of nutrients can be supplied for plant growth. In addition, application of bio-fertilizers like Azospirillum and Phosphobacteria, 2 kg each on 30th and 60th day after planting by mixing it with FYM (200 kg/acre) would also improve the crop growth. This can be applied in the sides of furrows and incorporated into the soil while earthing up.

Water management

It is always better to provide sufficient quantity of water on time rather than flooding the field with enormous amount of water. In conventional flooding method water is always applied more than the biological demand of the crop which may affect the crop growth.

After transplantation, the frequency of the irrigation may differ depending on the soil type, age of the crop, rainfall and moisture availability. For sandy soil, the frequency will be more and for clay soil it will be less.

Give irrigation once in 10 days during tillering stage (36-100 days), once in 7 days during Grand Growth period (101-270 days) and once in 15 days during Maturity period (from 271 days till harvest).

Furrow irrigation helps in proper application and saving of water. Alternate furrow irrigation means irrigating the furrows of odd numbers initially followed by irrigating the furrows of even numbers after 7 to 15 days as per the moisture content and age of the crop. This will ensure saving of water up to 50%.

Drip irrigation can be practiced effectively in SSI due to wider spacing and raising of single seedlings. Farmers who wish to adopt drip irrigation can contact the concerned firms and install them in their fields.

Harvesting

Harvesting in sugarcane is practiced in collaboration with the industry. Sucrose content in the plants will reach the desirable level on the 10th month after planting and ready for harvest within 12th month.

Overall benefits

In conventional method, cost of setts occupies the major part of cost of cultivation.

By practicing SSI, this seed cost can be reduced up to 75%.

Reduction in the plant mortality rate.

Increases in the length and weight of each cane.

It is easy to transport the young seedlings for longer distance.

Intercultural operations can be carried out easily due to wider spacing.

Opportunities offered by SSI

Addresses the issue of late planting by raising seedlings and their transplantation later on which actually advances the entire process.

Addresses the issue of narrow spacing as the technology is based on successful exploitation of sunlight and air by following wider spacing in the main field.

Addresses the problem of improper method of irrigation, namely, flooding.

Significant reduction in seed requirement, as only the bud is used as seed material.

Scope of SSI

Sugarcane productivity (more than 100 t/ha), has a great potential in SSI. The following are some of the reasons to the great impact of SSI in sugarcane sector.

Farmers are very much innovative, eager to take up any new technologies with great enthusiasm and support.

SSI will be a suitable option to solve the present problems of increasing seed cost, labour cost and other soil fertility and productivity related issues.

Due to wider spacing, intercultural operation becomes easy, thus reducing the drudgery among women labourers.

The wider spacing suggested in SSI are ideal in case of introducing Mechanical harvester, an effort already in practice in some of the Mills areas.

Conclusions

SSI involves use of less seeds, less water and optimum land utilization to achieve more yields. It is governed by some principles like using single budded chips, raising nursery, wider spacing, sufficient irrigation and intercropping. By practicing these measures, the following benefits can be realized

Better germination percentage.

High number of millable canes.

Reduction in the duration of crop to some extent .

Increased water use efficiency.

Improvement in accessibility to nutrients with optimum use of fertilizers.

More accessibility to air and sunlight.

Reduction in cost of cultivation and

Extra income from intercrops.

On the whole, by practicing SSI farmers can very well increase their productivity by reducing the use of inputs like fertilizers and saving the vital resources like water simultaneously. Hence, it is very much possible for sugarcane farmers to reap greater economical benefits by maintaining ecological sustainability.

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Chapter 9

Impact of INM with Nano P Fertilizer on Yield and Nutrient Uptake by Wheat in Vertisols

Sagar S. Patil
Department of Soil Science and Agricultural Chemistry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra
Email : sagarpatil4597@gmail.com

Abstract

The test weight (g), grain yield and straw yield (kg ha^{-1}) of wheat recorded highest under green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% 1000 ppm nano P fertilizer at tillering and flowering stage of wheat treatment 42.62 g, 3545.76 kg ha^{-1} and 4481.43 kg ha^{-1} respectively. Nitrogen and potassium uptake by wheat grain and straw recorded high when foliar spray of 0.5% 1000 ppm nano P fertilizer at tillering and flowering stage applied to wheat 68.68, 30.41 kg ha^{-1} and 11.57, 98.42 kg ha^{-1} respectively. Phosphorus uptake by grain and straw of wheat is higher under 50% RD of NP through fertilizer + Foliar spray of 0.5% 1000 ppm nano P fertilizer at tillering and flowering stage of wheat treatment + GM*15.35 and 9.01 kg ha^{-1} respectively. The study reveals that for optimum wheat yield, increase in P uptake by grain and straw and higher NPK use efficiency could be better accomplished with the application of under 50% RD of NP through fertilizer + Foliar spray of 0.5% 1000 ppm nano P fertilizer at tillering and flowering stage of wheat + GM*.

Key words : *Wheat, nano P fertilizer, green manuring, ghanjivamrut, jivamrut, nutrients, vermicompost, foliar spray.*

Introduction

Agriculture is the mainstay of the national economy of many developing countries in general and India in particular. Agricultural production and global food security are highly dependent on input fertilizers including nitrogen, phosphorus and potassium, as they add nutrients to the soil, promote crop growth and increase yields.

Wheat production in India in 2021-22 is estimated to be 105 million tons in area of 30.95 million hectare. However, India's wheat production stood at 109.59 million tonnes in the 2020-21 crop year (Anonymous, 2022). It is difficult to meet the food demand in future because of land is shrinking and pressure on production and productivity enhancement is also increasing. Productivity of wheat can only be enhanced by application of scientific tools and techniques in agriculture. Modern science basically deals with three areas *i.e.,* information technology, nanotechnology and biotechnology. These three sciences proved their worth in every sector of society, but agriculture is still lagging behind.

The response of P fertilizer in India's Vertisols was founds to be unpredictable and this was attributed to the high P fixation due to the high clay content and high smectite content. Vidarbha soils is dominated by smectite and ranges from 40 to 78 per cent. Currently, 5 per cent of Indian soils have sufficient P, 49.3 per cent in low grade, 48.8 per cent in medium grade and only 1.9 per cent in high grade (Pattnayak *et al*., 2009) only

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20-25 per cent of applied P is available for crops and remaining part of converted into insoluble into P solubilization of inorganic phosphorus in soil is majorly mediated by microbial activity due to secretion of organic acids like oxalic, malic, citric, acetic lactic, gluconic acid, propionic acid, butyric acid release during decomposition and by PSB which are the major solubilizers of phosphorus from resources.

The particle size of P fertilizers greatly affects their agronomic efficiency. The reduced particle size increases the specific surface area of ??the fertilizer, which increases the dissolution rate of fertilizers with low water solubility (Mortvedt, 1992). Nanoparticles should be ideal candidates for use as P fertilizers for plants.

Nano phosphate fertilisers are the greatest solution to boost phosphorus use efficiency as well as nutrient uptake and other crop yields. They also minimise phosphate fertiliser loss. together. The targeted release of nutrients in the right amounts by nano-fertilizers increases the effectiveness of fertiliser use without causing any damage to the soil or plants. (Rameshaiah *et al*., 2015).

Since, the productivity of wheat in Maharashtra is quite low and Nano P-fertilizer applied by foliar spray at important growth stages may effective in increasing growth of crops so there is need to study effect of INM with nano P fertilizer to maximize productivity and nutrient uptake by wheat.

Materials and Methods

1. Synthesis and characterization of nano P fertilizer

Synthesis of nano P fertilizer : Hydroxyapatite (HA) nanoparticles were prepared by chemical precipitation method as demonstrated by Mateus *et al.* 2007.

Hydroxyapatite powder was synthesized according to the following procedure : first, 1 liter of an aqueous fertilizer of H_3PO_4 (0.6M) was slowly added drop by drop to a 1 liter of an aqueous fertilizer of $Ca(OH)_2$ (1M) while stirring vigorously for about 2 hours at room temperature. Concentrated NaOH was added until a final pH of 9.5 was obtained. It is dried in oven at 80°C for 24 hours.

From collected HA powder weighed out 400 mg and dissolves it in 200 ml capacity beaker on the magnetic stirrer containing 50 ml of Milli-Q water slowly with the help of spatula. After adding HA powder kept it for 20 min sonication on sonicator instrument. Side by side took 100 ml capacity beaker containing 25 ml Milli-Q water on magnetic stirrer and dissolved 1% STPP (Sodium Tripolyphosphate) *i.e.,* 250 mg STPP pinch by pinch with the help of spatula. Add this 1% STPP solution of 250 mg drop wise in 200 ml HAP solution containing beaker. Kept all the 75 ml solution containing HAP + 1% STPP solution on magnetic stirrer for approximately 2 hrs. Then took 100 ml beaker contained 25 ml Milli-Q water on magnetic stirrer and added 250 mg of Pluronic F-68 pinch by pinch with the help of spatula. Then added firstly prepared 75 ml solution (HAP + 1% STPP solution) drop wise into freshly prepared Pluronic F-68 solution. After adding solution, it has been kept on magnetic stirrer for 10 minutes. Then keep solution for sonication on sonicator instrument for 20 minutes.

Characterization of nano P particles : After preparing the hydroxyapatite nanoparticles, different characterization techniques were used to study the particle size (nm), poly dispersion index (PDI) and counting rate (Kcps), zeta potential and other characteristics. morphological point.

Dynamic light scattering (DLS) : An essential tool for characterizing nanoparticles and other colloidal fluids is dynamic light scattering (DLS). DLS calculates the amount of light a laser scatters after travelling through a colloidal solution. The size of the particles in solution can be determined by examining the variation of the scattered light intensity as a function of time. The study is based on the Brownian motion of diffusion of particles in solution, wherein larger particles scatter more light than smaller particles and move more slowly. From the time dependence of the diffusion intensity measurements, one can determine the hydrodynamic diameter (diameter of a hypothetical non-porous sphere diffusing at the same rate as the characteristic particles). In dynamic light scattering there are two analysis methods are used (i) Cumulants analysis (ii) Distribution analysis. Cumulants analysis is use for determines a mean size and polydispersity index and distribution analysis is use for determines actual size distribution from suitable data.

According to conventional operating procedures at 25°C, dynamic light scattering was employed to confirm particle size (nm), count rate (Kcps), and polydispersity index (PDI). The particle size distribution of nanoparticles is ascertained using a laser diffraction approach with a multiple scattering methodology. 1 mL of the fertilizer from the cuvette was removed, and measurements were done at 25°C to determine the particle size and particle size distribution of the produced nanoparticles in an aqueous medium.

The Z-mean diameter (ZD) is the intensity weighted mean diameter obtained from the cumulative analysis. This average level characterizes the phenomenon of light scattering. It is very sensitive to the presence of aggregates or large contaminants due to the inherent strength weight.

The poly dispersity index (PDI) is defined as a dimensionless measure of the size distribution calculated from cumulative analysis. In the Zetasizer software, it goes from 0 to 1. Values ??greater than 1 indicate that the distribution is so scattered that the sample may not be suitable for measurement by DLS.

Zeta potential (also known as electrokinetic potential) is a measure of the "effective" charge on the surface of nanoparticles and quantifies the charge stability of colloidal nanoparticles. The amplitude of the Zeta potential provides information about the stability of the particle, with higher amplitude potentials showing increased electrostatic repulsion and thus increased stability. It is important to note that the magnitude of the charge on the surface of the nanoparticles depends on the pH of the solution. In fact, the surface charge that can decrease to zero at a particular pH is known as the isoelectric point.

A cell with two gold electrodes is used to measure the zeta potential by introducing a solution to the cell. The particles migrate in the direction of the electrode with the opposite charge when an electrode potential difference is introduced. The velocity of a particle is measured as a function of voltage using the Doppler method. The intensity of the scattered light oscillates at a frequency corresponding to the speed of the particles when a laser beam passes through the cell and the particles move across the laser beam. The zeta potential is calculated using the data collected from measurements of the particle speed at various voltages.

The zeta potential of the nanoparticles was also evaluated using the Malvern Zetasizer, Nano ZS-90. Zetasizer Nano ZS-90 uses Laser Doppler Velocimetry to determine electrophoretic mobility.

Scanning electron microscope (SEM) : The coarse and fine micro structures and the morphology of all the HA NPs were depicted by using Carl Zeiss scanning electron microscope (Model : EVO 18). Completely dried hydroxyapatite nanoparticle powder synthesized at pH 9.5 was mounted on 9 × 9 carousel sample holder. The extra powder was removed using air balloon and directly visualized under electron microscope using VPSE detector at.

Fourier-transform infrared spectroscopy (FTIR) : By exposing the samples to infrared (IR) radiation, Fourier transform infrared (FTIR) spectroscopy was utilized to confirm the functional group present on the surface of hydroxyapatite nanoparticles. By measuring the absorbance of a sample of infrared light at various wavelengths, FTIR analysis can be used to identify the molecular make-up and structure of a substance.

One milligram of dry, pH-9.5 produced hydroxyapatite nanoparticles and one hundred milligrams of potassium bromide (KBr) were used to make the pellets, which were then made using a KBr press. The pellet was subsequently added for analysis to the Perkin Elmer Spectrum II FTIR spectroscopy. With a spectral resolution of 4 cm^{-1}, scans in the 400 to 4000 cm^{-1} range were gathered for each spectrum.

Characterization of HAP NPs for particle size (nm), PDI and Kcps

Sr. No.	Details	fertilizer size (nm)	PDI	Kcps
1.	Nano P fertilizer for 1st spray	147.3	0.274	205.8
2.	Nano P fertilizer for 2nd spray	170.4	0.328	232.9

Experimental details

Design of the experiment and treatments.

The experiment was laid out in randomized block design with nine treatments each replicated thrice. The details of treatments are given below.

Location	:	Botany Research Farm, College of Agriculture, Nagpur.
Year of start	:	Rabi 2019
Year of study	:	2019-20
Soil type	:	Vertisols
Crop	:	Wheat
Variety	:	AKW-1071 (Purna)
Design of experiment	:	Randomized Block Design (RBD)
Number of replications	:	Three
Total number of treatments	:	Nine
Plot size	:	Gross: 4 × 3.15 m2 Net: 3 × 2.70 m2
Spacing	:	22.5 cm
Seed rate	:	100 kg ha-1
Method of sowing	:	Drilling
Recommended dose of fertilizer	:	100: 50: 50 NPK kg ha-1
Source of fertilizer	:	Urea, DAP, MOP and 1000 ppm P fertilizer

Treatment combinations

T_1	:	Absolute control
T_2	:	Green manuring + 100% RDF
T_3	:	Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.
T_4	:	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.
T_5	:	Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat
T_6	:	T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat
T_7	:	T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat
T_8	:	Green manuring + Ghanjivamrut 5 t ha^{-1}.
T_9	:	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + Jivamrut.

Green manuring = Green manuring of sun hemp (*Crotolaria juncea*)

(0.5% of 1000 ppm nano P fertilizer = 5.0 ml of 1000 ppm nano P fertilizer in 1000 ml of water)

Results and Discussion

Effect of INM with nano P fertilizer on grain yield of wheat

An appraisal of data in table revealed that yield of grain was significantly improved in due to various treatments. Among different treatments, T_5 (Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) increased wheat grain yield significantly over all other treatments.

Very low grain yield was recorded in absolute control (1657.40 kg ha^{-1}). The maximum grain yield (3545.76 kg ha^{-1}) was recorded under T_5, which was statistically at par with T_6, Among the organic input treatments of INM with nano P fertilizer, Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat treatment found comparatively better as compared to T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat (T_6) and GM* + 100% RDF (T_2) treatments.

Effect of INM with nano P fertilizer on straw yield of wheat

It is revealed that straw yield was significantly improved in due to various treatments. Among different treatments, T_2 (Green manuring + 100% RDF), T_3 (Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut), T_5 (GM* + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) increased wheat straw yield significantly over absolute control (2006.00 kg ha^{-1}). The maximum straw yield (4481.43 kg ha^{-1} recorded under T_5, which was statistically at par with T_2, T_3, T_4, T_6 and T_7 treatments.

Effect of INM with nano P fertilizer on test weight

The data on the weight of wheat grains affected by the different treatments are presented in Table 4 showing that T5 (Green manuring + 50% RD of Nano P by fertilizer + 0.5% foliar spray of 0.5% of 1000 ppm P at tillering and flowering stage of wheat) recorded a significantly higher test weight (42.62 g) of wheat, followed by T6 and T7. However, the treatment effect was not significant.

Among different treatments of INM with nano P fertilizer, Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage was found comparatively better as compared to T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat (T_6) and Green manuring + 100% RDF (T_2) treatments.

Above mentioned results point out that the treatment with Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat produced higher grain and straw yield in wheat which proposed that being an essential nutrient P acting a vital role in plant growth and development. Phosphorus has a great role in energy storage and transfer, P also stimulates early root development.

Pearl millet crop growth, yield, nutrient content, and uptake have been found to be greatly increased in several trials when nano- and chemical-phosphatic fertiliser was used (Dhansil *et al*., 2018).

Effect of INM with nano p fertilizer on yield attributes and yield of Wheat.

Treat. No.	Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Test weight (g)
T_1	Absolute control	1657.40	2006.00	38.43
T_2	Green manuring + 100% RDF	3340.21	4175.10	42.32
T_3	Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	3218.00	4019.00	39.53
T_4	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	3229.63	4076.35	41.12
T_5	Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	3545.76	4481.43	42.62
T_6	T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	3541.97	4453.65	42.20
T_7	T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	3216.93	4096.55	42.06
T_8	Green manuring + Ghanjivamrut 5 t ha^{-1}.	1902.37	2415.33	39.76
T_9	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + Jivamrut.	1965.72	2443.49	39.15
SEm ±		126.23	170.57	2.65
CD at 5%		378.45	511.38	NS

Effect of INM with nano P fertilizer on nitrogen content in grain and straw of wheat

Treat. No.	Treatments	N content (%)	
		Grain	Straw
T_1	Absolute control	1.82	0.60
T_2	Green manuring + 100% RDF	1.96	0.67
T_3	Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	1.87	0.63
T_4	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	1.89	0.64
T_5	Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	1.92	0.62
T_6	T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	1.94	0.68
T_7	T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	1.96	0.69
T_8	Green manuring + Ghanjivamrut 5 t ha^{-1}.	1.89	0.63
T_9	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + Jivamrut.	1.87	0.62
SEm ±		0.11	0.04
CD at 5%		NS	NS

Effect of INM with nano P fertilizer on nutrient content and uptake by wheat grains and straw

Nitrogen content in grain and straw of wheat

The result revealed that there was no significant effect of INM with nano P fertilizer by various treatments on grain and straw nitrogen content of wheat. The highest grain and straw uptake recorded in treatment T_7 (T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) which is 1.96 and 0.69 per cent respectively.

The maximum grain N uptake (68.68 kg ha^{-1}) recorded under T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat), which was at par T_2 (Green manuring + 100% RDF), T_3 (Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut), T_4 (Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment +

Nitrogen uptake by grain and straw of wheat

Effect of INM with nano P fertilizer on nitrogen uptake by grain and straw of wheat

Treat. No.	Treatments	N uptake (kg ha^{-1})	
		Grain	Straw
T_1	Absolute control	30.37	12.14
T_2	Green manuring + 100% RDF	65.60	27.96
T_3	Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	60.45	25.35
T_4	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	60.35	25.77
T_5	Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	68.09	27.81
T_6	T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	68.68	30.41
T_7	T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	63.12	28.32
T_8	Green manuring + Ghanjivamrut 5 t ha^{-1}.	35.96	15.22
T_9	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + Jivamrut.	36.78	15.22
SEm ±		4.44	1.92
CD at 5%		13.30	5.75

Effect of INM with nano P fertilizer on phosphorus content in grain and straw of wheat

Treat. No.	Treatments	P content (%)	
		Grain	Straw
T_1	Absolute control	0.26	0.155
T_2	Green manuring + 100% RDF	0.39	0.193
T_3	Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	0.36	0.173
T_4	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	0.36	0.176
T_5	Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	0.42	0.201
T_6	T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	0.44	0.193
T_7	T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	0.41	0.192
T_8	Green manuring + Ghanjivamrut 5 t ha^{-1}.	0.33	0.146
T_9	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + Jivamrut.	0.35	0.142
SEm ±		0.01	0.0032
CD at 5%		0.04	0.0096

50% RD of NP through fertilizer + Jivamrut), T_5 (Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_7 (T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) treatment. The maximum N uptake in T_6 treatment is might be due to green manuring with sun hemp, azophos seed treatment and vermicompost.

Treatment T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat), T_5 (Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_4 (Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut) recorded significantly higher straw uptake of N as compared to absolute control (12.14 kg ha^{-1}). The highest straw N uptake (30.41 kg ha^{-1}) was recorded under T_6, which being on par with T_2, T_3, T_4, T_5 and T_7 treatments.

Effect of INM with nano P fertilizer on phosphorus uptake by grain and straw of wheat

Treat. No.	Treatments	P uptake (kg ha^{-1})	
		Grain	Straw
T_1	Absolute control	4.25	3.09
T_2	Green manuring + 100% RDF	12.91	8.06
T_3	Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	11.53	6.96
T_4	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	11.49	7.32
T_5	Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	15.35	9.01
T_6	T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	14.87	8.62
T_7	T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	12.64	7.88
T_8	Green manuring + Ghanjivamrut 5 t ha^{-1}.	6.59	3.52
T_9	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + Jivamrut.	6.55	3.61
SEm ±		0.49	0.32
CD at 5%		1.48	0.96

Potassium content in grain and straw of wheat

Effect of INM with nano P fertilizer on potassium content in grain and straw of wheat

Treat. No.	Treatments	K content (%)	
		Grain	Straw
T_1	Absolute control	0.233	1.810
T_2	Green manuring + 100% RDF	0.333	2.203
T_3	Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	0.296	2.066
T_4	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	0.306	1.970
T_5	Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	0.310	2.146
T_6	T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	0.326	2.210
T_7	T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	0.336	2.180
T_8	Green manuring + Ghanjivamrut 5 t ha^{-1}.	0.286	1.953
T_9	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + Jivamrut.	0.283	1.930
SEm ±		0.0084	0.0127
CD at 5%		0.0254	0.0383

Phosphorus content in grain and straw of wheat

P content in grain was found significantly higher under T_6 (0.44%), but it was remains at par with T_5 (Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_7 (T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) treatments.

P content in straw was significantly higher under T_5 (0.201%), it remains at par with treatment T_2 (Green manuring + 100% RDF), T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_7 (T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) treatments.

Phosphorus uptake by grain and straw of wheat

P uptake by grains found highest in T_5 treatment *i.e.,* Green manuring + 50% RD of NP through

Effect of INM with nano K fertilizer on potassium uptake by grain and straw of wheat

Treat. No.	Treatments	K uptake (kg ha^{-1})	
		Grain	Straw
T_1	Absolute control	3.84	36.31
T_2	Green manuring + 100% RDF	11.13	91.99
T_3	Green manuring + Ghanajivamrut 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	9.56	82.99
T_4	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + 50% RD of NP through fertilizer + Jivamrut.	9.96	80.26
T_5	Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	10.99	96.21
T_6	T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	11.57	98.42
T_7	T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat	10.83	89.29
T_8	Green manuring + Ghanjivamrut 5 t ha^{-1}.	5.44	47.17
T_9	Green manuring + Vermicompost 5 t ha^{-1} + Azophos seed treatment + Jivamrut.	5.57	47.16
SEm ±		0.52	3.40
CD at 5%		1.54	10.19

fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat (15.35 kg ha^{-1}) which was at par with T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) treatments.

P uptake by wheat straw recorded highest in T_5 (9.01 kg ha^{-1}) treatment which is of green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat. T_5 is at par with T_2 (Green manuring + 100% RDF) and T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) treatments.

K content in grain was found significantly higher under T_7 (0.44%), but it was remains at par with T_2 (Green manuring + 100% RDF), T_5 (Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) treatments.

K content in straw recorded highest under treatment T_6 (T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) *i.e.,* 2.210%. T_6 treatment is at par with the T_2 and T_7 treatment.

It could be seen from results that the highest K content was observed in wheat straw as compared to grain. The results are in conformity with the findings of Vyas *et al.* (1997) and Khushare (2003).

Potassium uptake by grain and straw of wheat

K uptake by grains found higher in treatment T_6 (11.57 kg ha^{-1}) *i.e.,* T_3 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat. T_6 treatment is at par with treatments T_2 (Green manuring + 100% RDF), T_5 (Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_7 (T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat).

K uptake by wheat straw recorded highest in T_6 treatment (98.42 kg ha^{-1}). T_6 treatment at par with T_2 (Green manuring + 100% RDF), T_5 (Green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) and T_7 (T_4 + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat) treatments.

Conclusions

Nano P fertilizer or hydroxyapatite nano fertilizer (HAP NPs) of mean size 145 to172 nm was synthesized successfully and characterized through DLS, SEM and FTIR. The nanoparticles of size range 145 to 172 nm of mono dispersed nature with a zeta potential of -47.18 mV (stable range) were formed.

From yield point of view, green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and flowering stage of wheat found significantly beneficial to obtain maximum wheat yield.

Under green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at tillering and blooming stage of wheat, phosphorus uptake by grain and straw was much increased. The INM with nano P fertilizer found similar with phosphorus application through conventional sources, indicating that chemical load and fertilizer expense may be decreased without harming wheat production.

The results of the current study therefore suggested that the application of green manuring + 50% RD of NP through fertilizer + Foliar spray of 0.5% of 1000 ppm nano P fertilizer at the tillering and flowering stages of wheat could better accomplish the optimum wheat yield, enhancement of phosphorus uptake by grain and straw, and higher nitrogen, phosphorus, and potassium uptake.

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Chapter 10

Post-Harvest Management of Spices

Sowmya Kumari[1] and Sachin U.S.[2]
[1]*Department of Horticulture, CoA, Shivamogga*
[2]*KVK, Bramhavara, KSNUAHS, Shivamogga*

Introduction

Spices and spice products are most important natural flavouring materials available to the food processors. They have wide applications in food and non-food items. Most of the herbs and spices are composed of different types of ingredients—non-volatile components which may be extracted as oleoresin or resinoids by using selected solvents and inert matter which is mostly cellulose comprising basic cellular plant structure and of value as natural carrier or dilutent as well as contributing bulk or weight. Pepper, cardamom, cinnamon, clove, nutmeg, ginger and turmeric, are important spices grown commercially in India.

Black Pepper

Pepper is harvested from December to March in Kerala. Generally it takes 180–230 days after flowering to reach full maturity. Harvesting at immature stage reduces the bulk density. It should be done when some of the spikes in vine turn red. If there is a wide difference in maturity between spikes in a particular vine, selective harvesting should be adopted. The bulk density of pepper ranges between 425 and 850g/litre. Starch accounts for 34% in black pepper and 56.5% in white pepper.

Despiking

If the harvested spikes are kept in bag for 12–24hr or heaped and covered overnight, despiking becomes easy. Trampling with legs is the traditional method followed for despiking. Mechanical devices are also available for this purpose, which are more convenient, hygienic and time-saving.

Drying

During ripening stage, weight of the pepper decreases. Moisture content is reduced from 82.5% at pin-head stage to 60% and 40% at ripening stage. This is a process to ensure more black colour and to reduce the drying time. Generally pepper is dried after despiking and the product may assume a brownish tint. If the despiked berries are taken in a perforated vessel and dipped in boiling water for one minute and then dried, it becomes a black shining product. This process enhances the activity of the enzymes found in black colour.

Drying surface

Traditionally pepper is dried under sun. It requires about 6–7 days for complete drying to a moisture level of 8–10%. Fenugreek-coated bamboo mat is ideal to dry pepper. Another ideal surface is cement floor. Low-density and high-density polyethylene sheets are good for drying. Its main advantages are black polyethylene sheets which absorb more heat and hence reduce drying time. The sheets can be folded along with pepper and hence and daily routine of spreading the material in the morning and collecting them in the evening can be avoided. However, great precaution is necessary to prevent the scattering of berries, as it is very smooth. Solar driers can also be used for drying.

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Mechanical driers using electricity can also be employed for drying. To reduce the cost, partial sun-drying followed by mechanical drying can be adopted.

Dry recovery

Some precautions should be followed while processing. Select pepper varieties which ripen uniformly, have good berry size, oil and oleoresin. Avoid residues of chemicals by effective management of pests and diseases. Harvesting before maturity leads to loss in weight, while delay in harvesting leads to berry shedding. Strict hygiene should be maintained in harvesting, despiking, heaping and drying. Keep maximum moisture content (11%) in dried produce. Store pepper in clean bags and they should not touch walls/floor directly. The rooms where pepper is stored should be safeguarded from rodents, insect pests, birds, animals etc. Do not mix immature and ripe berries. The pepper should never be stored in rooms where fertilizers, pesticides etc. are stored.

Value-added products

White pepper, pepper powder, pepper oil, pepper oleoresin, dehydrated green pepper, piperine, pepper in brine, pink pepper, frozen green pepper and encapsulated spices are value-added products.

White pepper : It is prepared by removing the outer pericarp (skin) of berries by different methods namely water steeping, steaming or boiling and decortication. In water steeping method, fresh, ripe spikes or berries are packed in gunny bags or steeped as such in water tanks or running water for 7–10 days. The pin-heads and light berries, which float are separated. Once the skin is softened, they are rubbed by hand or trampled to remove their outer skin. The deskinned berries are sun-dried and sold as white pepper. Recovery of white pepper varies from 22–27% of the green pepper. White pepper can also be prepared from black dried pepper by steeping them in water for 15–20 days. Thereafter, they are rubbed, washed, steeped in bleaching solution, washed and sun-dried. In decortication, white pepper are prepared by decorticating black peppers in decorticating machines. However, a loss of about 20–25% of berries is incurred due to breakage in this method.

Pepper oil : The characteristic aroma of pepper is due to 2–5% volatile oil. Generally slightly immature pepper has more oil. Balankotta and Subhakara pepper varieties have high oil content.

Pepper oleoresin : It is the concentrate of all the flavour components (aroma, taste, pungency and related sensory factors) and it truly recreates, (when diluted) the sensory quality of the original material. It is extracted from powdered black pepper using solvents like acetone, ethylene dichloride etc.

Piperine : The alkaloid piperine (3–6%) is the major constituent responsible for biting taste of black pepper. Other pungent alkaloids are chavicine, piperidine and piperettine.

Green pepper in brine : Bottled green pepper has great demand in non-traditional areas. The green colour is maintained under high salinity of steeping liquid. Minimum salt level should be 12%. Addition of small amount of citric acid prevents the discolouration due to phenols.

Dehydrated green pepper : Keeping the freshly harvested despiked pepper in boiling water for over 10 minutes inactivates the bleaching enzyme. Treatment with sulphur dioxide reduces the chances of darkening. As sun-drying destroys chlorophyll and green colour, to make dehydrated green pepper, drying should be done in hot air oven or microwave oven.

Frozen green pepper : It is prepared using blast freezers. Such peppers on thawing are almost equal to fresh material. Other products like spice essences and emulsion, spice decoctions, encapsulated spices fat-based spices etc. are also prepared from black pepper.

Cardamom

Its ripe fruits (physiologically ripe) are generally harvested. Splitting of capsules is done in mature capsules. Percentage of dry recovery is highest (20%) in fully ripe capsules followed by those harvested at physiological maturity (24%) and in immature stage (14%). Capsules may be washed in water to remove the adhering soil and treatment with 2% washing soda (alkali) for 10 minutes enables to retain green colour and prevent mould growth.

Curing

Curing of cardamom is nothing but drying at low temperature. In this process, moisture of green cardamom is reduced from 80–12% at 50°C so as to retain their green colour to the maximum extent. The sun-drying is followed for less quantity (50kg). It requires about 5–6 days for complete drying. Cardamom is spread over the low-density and high-density polyethylene sheets or bamboo mat or cement floor. Solar-driers can also be used for drying cardamom. In electrical drier, cardamom can be dried in tray type electrical dryer fitted with exhaust fan in 10–12hr at 45°–50°C. Drying at low temperature helps retain green colour as well as avoid splitting of capsules. Pipe curing/drying in curing house is the best method of curing at a large scale to get high quality green cardamoms. It consists of walls made of bricks or stones and tiled roof with ceiling. A pipe made of iron or zinc sheet starting from the furnace passes through the chamber and opens outside the roof. The flue gas generated in the furnace passes through the pipe and heats the pipe. Conduction as well as radiation heat up the air surrounding the pipe. Then by natural heat convection, the entire room is heated. In modern curing houses, exhaust fan is also fitted. The exhaust fans located on either sides of the wall uniformly spread the temperature as well as it draws out high humid air, particularly at the beginning of drying, from the drying chamber. Inside the room, cardamom is kept in wooden/aluminium trays arranged in racks. Fire in the furnace is adjusted to maintain the temperature of 45°–50°C. It may take about 18–22hr. for drying. Though many other types of mechanical driers are available, curing house is still used by most of the planters.

Value-added products

Bleached cardamom is creamy-white or golden-yellow. In can be done with either dried or freshly-harvested capsules. It is prepared using sulphur dioxide, potassium metabisulphite (25g containing 1% HCl for 30 minutes) and hydrogen peroxide (4–6% and pH 4.0). However, bleached cardamom lose more volatile oil.

Cardamom oil is a major value added product. Most varieties contain 5–9% oil. Immature cardamom has more oil. Unlike pepper and ginger, cardamom oil imparts full taste of the spice. Major chemical constituents of the oil are 1, 8-cineole and a-terpinyl acetate. A high terpinyl acetate and low cineolic content in the oil impart sweet flavour, while a high cineolic content impart more of an undesirable camphoraceous note to the oil.

Turmeric

Curcumin is the principal colouring pigment in turmeric. Indian turmeric is popular for its intrinsic quality. Some precautions are necessary to preserve its quality. Seed turmeric should be immersed in suitable fungicide and pesticide for half an hour. Thereafter, it may be dried in shade and kept safely. Robust rhizomes are suitable for seed material. Larger rhizomes can be split and used. Harvesting should be done at maturity without damage and the rhizomes may be washed. Turmeric should be boiled and dried. For boiling, use clean water. The bulbs and the fingers should be boiled separately. While boiling, water should be filled in to cover the turmeric. Cover the turmeric using gunny bag or jute bag to restrain the steam within.

Heating should be uniform. After the commencement of boiling, it takes 45–50 minutes to complete the cooking process. It can be tested by passing between fingers or by piercing a small stick through the rhizome, which easily passes through if properly boiled. The odour of the smoke too indicates that it is fully cooked.

Clean terraces or cemented yards or clean bamboo mats should be used for drying. It should be heaped and covered during night to protect it from rains. It may take about 10–15 days and if the drying is complete, turmeric breaks with a metallic twang. Dried turmeric can be marketed as such or after polishing is done by sprinkling turmeric powder using a mechanical drum. It should be kept in clean sacks and stored over wooden platforms in store rooms. The room should be kept clean, free from pests, spiders and rodents. Cowdung smeared floor or mats should not be used for drying. Dried turmeric should be stored safely.

Alleppy finger turmeric is very famous for its colour in trade. In turmeric, curcumin content varies from 4–7%. There are quite a few varieties available which have more then 6% curcumin content.

Ginger

The quality of ginger products depends on variety and its cultivation practices. Appropriate variety is selected for various end products—dry ginger, raw ginger, ginger oil, oleoresin etc.

Himachal, Maran, Mananthody and Kuruppampady are good varieties to prepare dry ginger, whereas Rio-de Janeiro, China Wynad and Varada are good for raw ginger. Only recommended doses of pesticides and other chemicals should be applied to avoid their residues. Ginger rhizomes should be thoroughly cleaned before peeling. Extreme care is necessary while peeling to prevent loss of volatile oil. Wooden scrapers of bamboo stick are ideal for peeling. Knives or sickles may leave dark spots. Ginger can be dried on clean bamboo mats or cement floor.

Depending on availability of sunlight full drying period may vary from 7–14 days. Desirable moisture level is 10%,above which it may cause development of aflatoxin. The dried ginger should be packed in air-proof polyethylene bags and then stacked on wooden platform.

Rhizomes affected with rot should not be used for preparing dry ginger. Fumigation of stored dry ginger should not be done without consulting experts as many importing countries have imposed a ban on fumigated materials. Mixing of fully dried ginger with half-dried one may be avoided. Rodents, birds, pests and animals should not be allowed in the area where ginger is stored. The major Indian trade types are Cochin and Calicut ginger. Cochin ginger is superior in quality. Appearance, contents of volatile oil and fibre, pungency level and a subjective assessment of aroma and flavour are important in the quality evaluation of dried ginger. This depends on cultivars and stage of maturity at harvest. Oil and oleoresin decrease as maturity progresses.

Value-added products

Ginger oil (0.5–3.0%) possesses only aroma and not the flavour of the spice. Ginger oleoresin is a blend of oil and resinoides. It is extracted from ginger powder using organic solvents like acetone, ethylene dichloride etc. Its content is 3.5–9.5%. Major pungent principle is gingerol (a phenyl ketone).

Ginger preserve or muraba, ginger candy, soft drinks like ginger cocktail (which aids in digestion), ginger pickles, salted ginger, salted in vinegar or vinegar or vinegar mixed with lime and green chilli are important value-added products prepared form fresh ginger.

Clove

Clove clusters are picked by hand when the buds have reached their full size and most of them develop a pronounced pink flush. From these clusters, cloves are separated from the stems consisting of peduncles and pedicel. Then it is dried. Dry cloves weigh one-third the weight of green, freshly harvested cloves. Quality of the dried spice is influenced by a number of factors—care taken in harvesting, drying and storing. Traditional method of drying is exposing it to sun on mats. Green buds are spread out in a thin layer on the drying floor and are raked from time-to-time to ensure uniform colour. It may take about 4–5 days to produce a spice of desirable colour. When properly dried, they have a bright brown colour and snap cleanly and do not bend when pressed across the thumb nail.

Value-added products

Clove bud oil is superior in odour and flavour to stem and leaf oil. Bud yields about 17% oil. It contains about 85% eugenol. Methy1-n-amyl ketone is present only in bud oil. Its stem has 5–7% oil containing 70–90% eugenol. The leaves also have 1.5–1.8% oil. Oleoresin is prepared by cold or hot extraction of the crushed spice using organic solvents. Volatile oil content of oleoresin is usually 70–80%.

Cinnamon

Cinnamon bark and leaves are commercially very important. Bark is used to extract oil and oleoresin and leaf for oil. Bark oil has high cinnamaldehyde content whereas leaf oil high eugenol. Cinnamon bark is extracted generally after the rains at the time when the red flush of young leaves turns green and their sap flows freely. The process consists of stripping the bark and preparing quills from the inner bark. The outer bark is first removed using a crude curved knife. The stripped stem is rubbed briskly with a heavy brass rod to loosen the inner bark. Two cuts are made round the stem about 30cm apart and 2 longitudinal slits are made on the opposite side of the stem. The inner bark is then carefully eased off the wood with the pointed side of the knife. The curled pieces of inner bark are next assembled into quills or pipes.

Value-added products

Oleoresin is extracted from powdered cinnamon bark using acetone, ethylene dichloride etc. Cinnamon has about 7–10% oleoresin. Bark oil is obtained from its bark. The bark has 0.5–2.5% oil in it. It contains about 65% cinnamaldehyde and 5–10% eugenol. Its leaves also contain 05–15% oil. Its main constituent is eugenol (70–80%). It is used in dental preparations and synthetic vanillin.

Cinnamomum cassin is another important spice with great commercial potential. Its bark and leaf have cinnamaldehyde as the main ingredient.

Nutmeg and mace

Nutmeg is generally harvested when its fruits split. The seeds with surrounding scarlet aril are removed from the pericarp. Later the mace is taken off and dried separately from the nutmeg in its shell. The proportion of dried shelled nutmeg to dried mace is approximately 20:3. After harvesting, nutmegs are dried in their shells either under sun or by mechanical drying.

Value-added products

It contains 25–40% fat which can be recovered using solvents or by mechanical ressing. It is highly aromatic. Major constituent is trymyristicin. Oleoresin is extracted with solvents. It may have butter also. About 7–16% nutmeg oil is found in it. Aromatic ethers, myristicin and elemicin are present in oil and oleoresin. Both these have hallucinating property. Hence the oil may be used for consumption only in small quantities. About 4–17% mace oil is obtained.

Allspice

Dried berries are a major item of commerce. It has about 3–4% of aromatic steam volatile oil and fixed (fatty) oil. They have resin, protein, pentosans, starch, traces of alkaloids, pigments and minerals. Volatile oil from berry is yellow to brownish possessing a warm spicy and sweet odour. Main components are eugenol (68%), methyl eugenol (8%), betacaryophyllene (4.2%), humulene (2.7%) and cineole (2.3%).

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Chapter 11

Application of Artificial Intelligence and Robotics in Agriculture

Y.S. Chavan*, P.S. Bodake, T.N. Thorat and S.S Kinge
Department Agronomy, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra
**Corresponding Author Email : chavanyashpal68@gmail.com*

Introduction

Agriculture is facing new major challenges nowadays. The global population is expected to reach more than nine billion by 2050, requiring a growing in agricultural production by 70 % in order to suit the demand. Only about 10 % of this growth may come from availability of unused lands, with the result that the rest of 90% will need to come from intensification of current production (FAO). Intensification in agriculture sets a high pressure on energy, mainly represented by fossil fuel, the supply of which is predicted to be insufficient to meet the demand over the next 15-20 years without radical measures and investments in all over the world (Kfm. Jorg Schindler). The gap between available water supply and water demand is increasing in many parts of the world. By 2025 over three billion people are likely to experience water stress (UNDP).

In recent years, an explosion in applications of Artificial Intelligence (AI) specifically in the domain of health care, weather forecasting, space programmes, automation, agriculture, etc. has been observed. The introduction of AI to agriculture will be enabled by other technological advances, including big data analytics, robotics, the internet of things, the availability of cheap sensors and cameras, drone technology, and even wide-scale internet coverage on geographically dispersed fields. By analyzing soil management data sources such as temperature, weather, soil analysis, moisture, and historic crop performance, AI systems will be able to provide predictive insights into which crop to plant in a given year and when the optimal dates to sow and harvest are in a specific area, thus improving crop yields and decrease the use of water, fertilizers, and pesticides. Via the application of AI technologies, the impact on natural ecosystems can be reduced, and worker safety may increase, which in turn will keep food prices down and ensure that the food production will keep pace with the increasing population.

Internet of Things (IOT)

IoT is an environment where objects, animals or people are equipped with unique identifiers capable of data transmission over Internet network without the need for human-human or human-computer interaction. The Internet of Things is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields—from wireless sensors to nanotechnology. IOT applications encompass diverse areas including agriculture, healthcare, retail, transport, environment, supply chain management, infrastructure monitoring etc. Precision agriculture is the new term appended to the agriculture filed, with all the procedures being followed, addressed, and simulated in a tech-driven manner. Applications in agriculture include soil and plant monitoring, greenhouse environ monitoring and control systems, monitoring of food supply chain, monitoring of animals, etc. Precision agriculture, therefore, aims to optimize and improve agricultural processes to ensure optimum production with reliable, fast, and distributed dimensions thus providing

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growers a detailed overview of the ongoing scenarios in the cultivation stretches. This practice is followed to reduce energy consumption. The major areas where IoT can leave an everlasting impression are climate monitoring, data analytics, early disease detection, crop counting, smart irrigation, etc. With the spread of a network of devices, a communication channel can be established between the farmers, fields, and experts. By developing IoT based models, the field conditions can be monitored remotely on regular time intervals without any human intervention and after analysing the data favourable and efficient decisions can be taken accordingly. This will help to ensure both field and market safety and security to the farmer.

Scope of AI in Agriculture

Traditional agricultural practices used by farmers are not adequate to fulfil the increasing demand. To serve this increasing demand, farmers need to adopt the latest advancements in agriculture such as use of state-of-the-art tools/machinery and AI based techniques. The concept of cognitive computing is the one which imitates human thought process as a model in computer. This results as turbulent technology in AI powered agriculture, rendering its service in interpreting, acquiring and reacting to different situations (based on the learning acquired) to enhance efficiency. The various areas where the solutions for benefitting agriculture involving AI are furnished below.

AI in Irrigation

Agriculture uses 85 percent of the world's total freshwater energy. As well as this proportion is steadily rising in tandem with demographic growth as well as rising food demands well as. As a result, we'll need to develop more efficient solutions to ensure that water supplies are well used in irrigation. Smart irrigation technology is being developed to maximize productivity without the use of a large number of people by sensing water levels, soil temperature, nutrient quality, as well as weather forecasting. The architecture of proposed IoT based smart irrigation system is shown in Fig. 1. It has three different layers, i.e., Data collection and transmission layer, Data processing & intelligence layer and application layer of IoT.

Depending on the field requirements, a standalone sensor node or a wireless sensor network of the sensor nodes may be deployed. In standalone scenario field data collection device consists of four sensors, viz., VH-400 Soil Moisture sensor, Soil temperature sensor, DHT22 temperature and humidity sensor, and Ultraviolet (UV) Light Radiation sensor based on GUVA-S12SD and SGM8521 Op Amp. The output of these sensors is read by an Arduino-Uno, which is connected to Raspberry Pi (R-Pi). In R-Pi a program is written in Python language to hourly fetch the data from sensors and to store the data in SQLite database, which is synched with the server database using developed web service. In data processing & intelligence layer Web services were developed to process different tasks, viz., Web service for field sensor data collection, Web service for online weather data collection, Soil moisture prediction algorithm, Responsive web-based interface for real-time monitoring, Web service to control water motor, IoT enabled water pump. Also, algorithms for soil moisture prediction and irrigation scheduling were developed for data processing.

Disease and Pest detection

Traditional methods of monitoring crop health are time-consuming and inefficient especially for larger areas of thousands of acres. Many researchers have developed many AI-based architectures to overcome the challenges identified in the arena of traditional agriculture.

AI-based techniques with inclusion of image processing, deep learning, and data analysis provide an easy and effective way for disease prediction and health monitoring. The system captures crop images using high definition (HD) camera-enabled drones, unmanned aerial vehicles (UAVs), or satellite imagery. The captured images are used as dataset for training of Convolution Neural Networks (CNNs), a class of Artificial Neural Network (ANN). CNNs extract useful features from fed images and make predictions about diseases and pests in crops. The system is effective in continuous monitoring of health of plants and hence gives better solutions for calculating amount of pesticides to be used and time to use a pesticide.

Crop Readiness Identification

AI-based system captures images of a crop and analyses them for determining the crop readiness in a particular area for harvesting. Images of various crops captured under white light and UVA light are to check how ripe the green fruits are. From this analysis farmers can create different levels of readiness based on the crop/fruit category and add them into separate stacks before sending them to the market. Also, use of

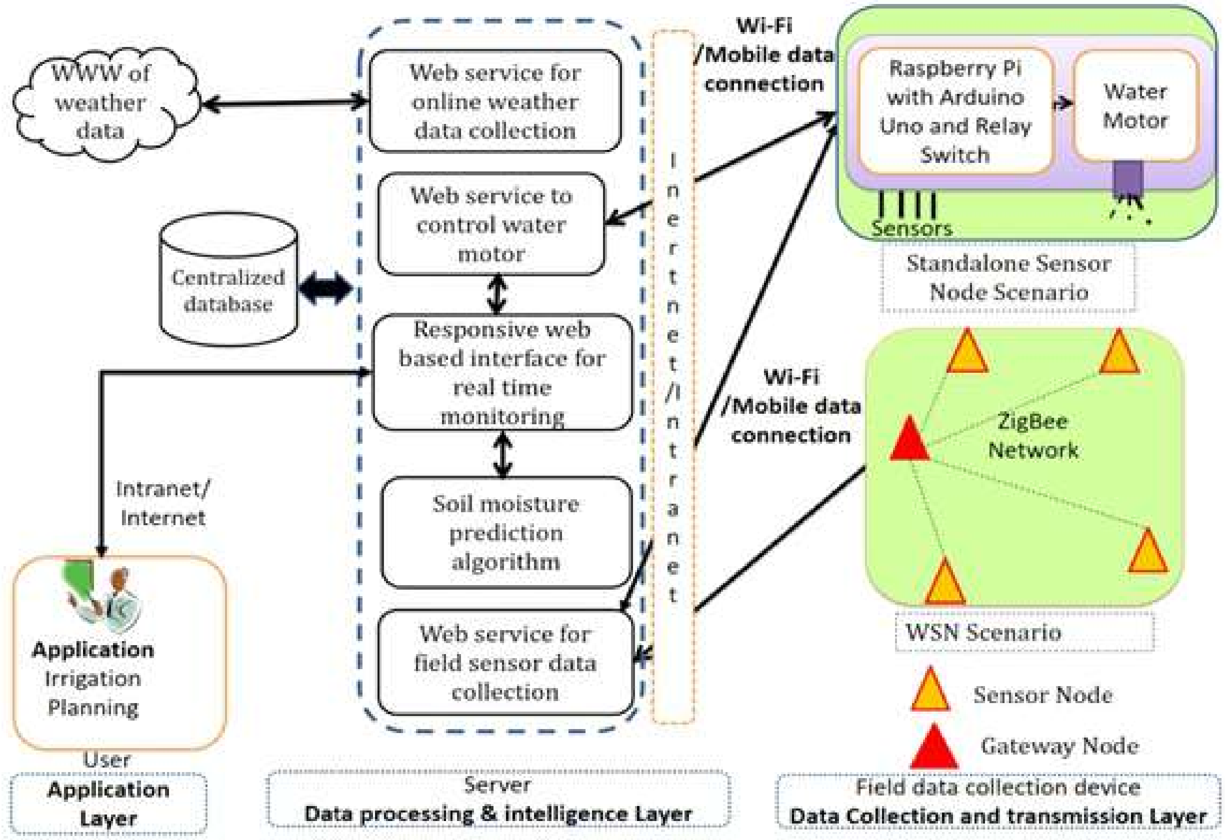

Fig.-1 : IOT based irrigation system.

multiple sensors e.g., high-resolution RGB, multispectral, hyperspectral sensors provide precise and accurate analysis of crop readiness identification.

Sensors for Crop Monitoring

Various sensors viz., RGB imaging, Multi and hyperspectral reflectance sensor, Thermal sensors, Fluorescence imaging, 3D imaging are used for crop monitoring. The optical sensors work on the principle of optical properties of leaves for crop monitoring. The optical properties of leaves are characterized by (i) light transmission through a leaf, (ii) light that is absorbed by leaf chemicals (e.g., pigments, water, sugars, lignin and amino acids), and (iii) light reflected from internal leaf structures or directly reflected from the leaf surface. Thus, reflectance of light from plants is a complex phenomenon dependent on multiple biophysical and biochemical interactions. The visible range (VIS 400 to700 nm) is mainly influenced by leaf pigment content, the near-infrared reflectance (NIR 700 to 1,100 nm) depends on the leaf structure, internal scattering processes, and on the absorption by leaf water, and the short-wave infrared (1,100 to 2,500 nm) is influenced by the composition of leaf chemicals and water (Carter and Knapp). Changes in reflectance due to plant pathogens and plant diseases can be explained by impairments in the leaf structure and chemical composition of the tissue during pathogenesis that is highly specific, e.g., succession of chlorotic and necrotic tissue or the appearance of typical fungal structures, such as powdery mildew hyphae and conidia or rust uredospores (Fig.-4A and B). Whereas biotrophic fungi such as powdery mildews or rusts have a relatively low impact on tissue structure and chlorophyll composition during early infection (Fig.-4A and B), perthotrophic pathogens, such as those that cause leaf spots, often induce degradation of tissue due to pathogen-specific toxins or enzymes that ultimately results in necrotic lesions. In contrast, powdery mildews and rust fungi produce fungal structures on the leaf surface that can influence the optical properties of the plant-pathogen interaction.

Yield Mapping/Monitoring

Yield mapping refers to the process of collecting georeferenced data on crop yield and characteristics, such as moisture content, while the crop is being harvested. Yield monitors are a rather recent

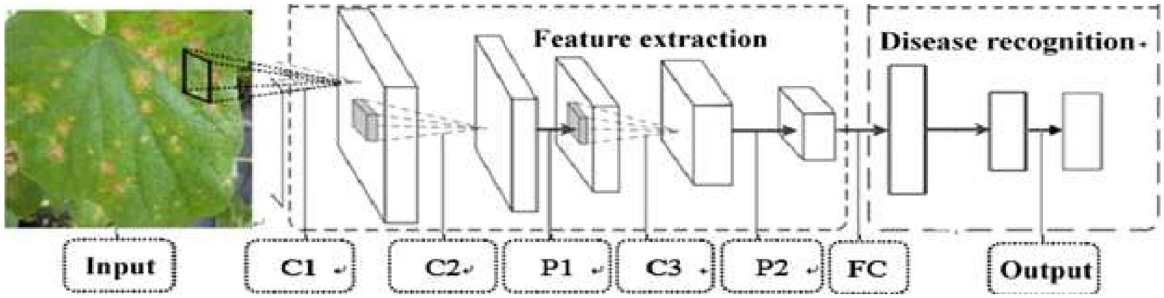

Fig.-2 : Convolutional neural network (CNN) based model for disease and pest detection.

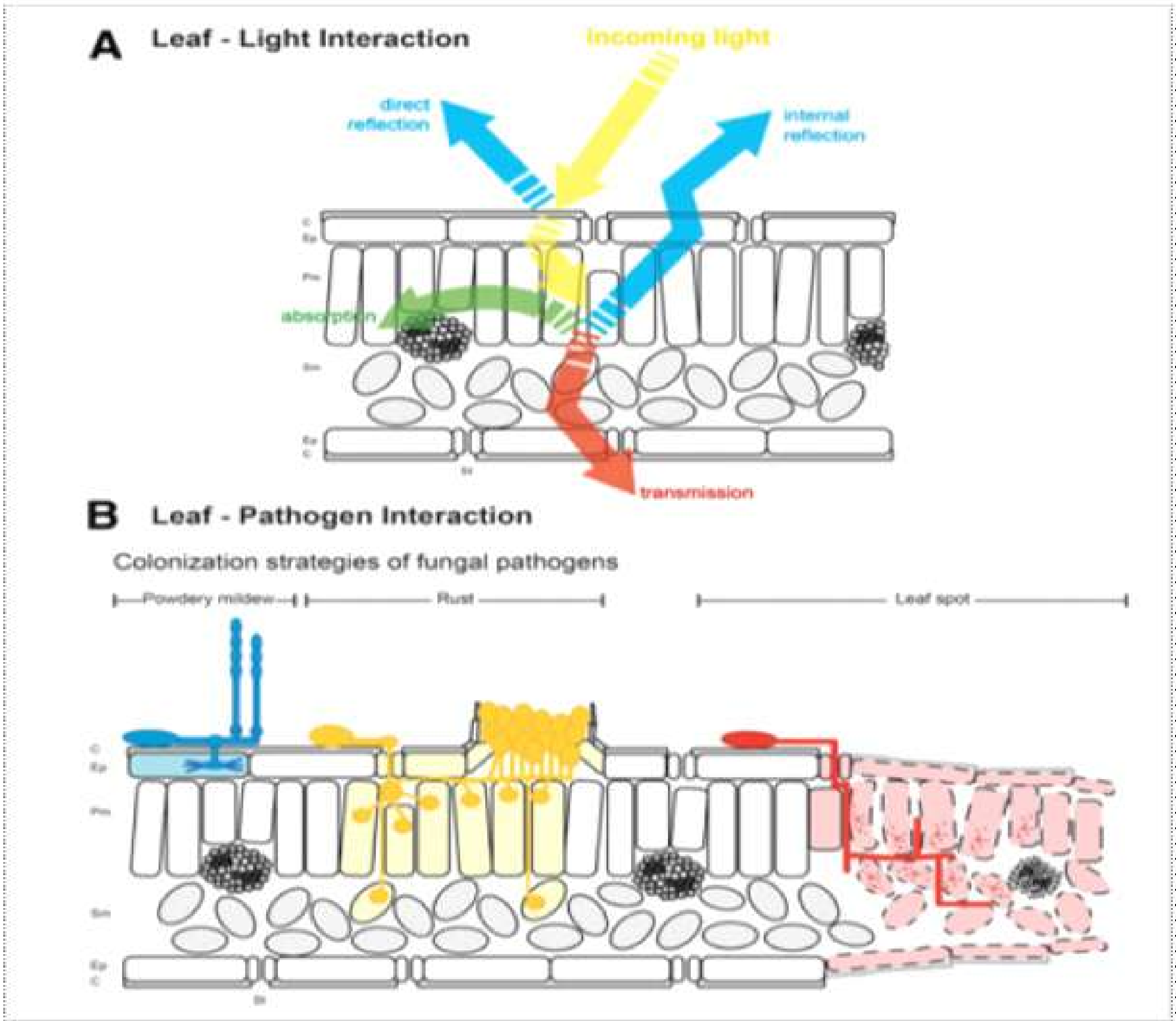

Fig.-4A : The interaction of leaf tissue with light depends on structural and leaf chemical properties. Fig.-4B. During pathogenesis, leaf pathogens influence leaf structural and chemical properties, and by this the leaf optics are altered.

development and allow farm equipment such as combine harvesters or tractors to gather a huge amount of information, including grain yield, moisture levels, soil properties, and much more. Due to the fact that yield monitors provide farmers with so much information, they are much more able to assess things such as when to harvest, fertilize or seed, the effects of weather, and much more. Yield monitors work in three very simple steps: the grain is harvested and fed into the grain elevator which has sensors that read moisture content of the grain. After that process as the grain is being delivered to the holding tank, more sensors monitor the grain yield. As both of these sensors work the information is sent to the driver cab and is displayed on a screen, as well, the information is geo-referenced so it can be mapped as well as closely investigated on a later time or date. There are many benefits for farmers to use yield monitoring technology, although one main benefit is that it helps to give the farmer accurate and often geo-referenced data about their field. A farmer can better understand crop yield and crop related information to mitigate potential threats or enhance possible opportunities. Other benefits with a yield monitoring system include the ability for a farmer to export the information onto a personal computer, allowing this information to be available in a variety of different formats, including in equipment displays, at home, or printed. Also, in the home or office a farmer can used specialized computer software to asses and better understand the recorded information. Yield monitors can monitor grain by a field by field or load by load basis, this gives the farmer a huge amount of flexibility as well as provides him or her with instant information about the load they have gathered.

Challenges for adopting AI in Agriculture

Cost **:** Designing a cost-optimized model is still a difficulty faced by many authors. Scientists are focusing on developing cost efficient systems by reducing the hardware and software requirements in IoT deployments. Economic differences of countries make it difficult for farmers to deploy devices and technology. So, it is important to develop some economic models.

Heterogeneity : While designing a system, heterogeneous devices are used. Every device differs in processes and services requirements. In the case of agriculture, most models perform with heterogeneous devices, so it is important to create interaction between heterogeneous modules and communication technologies. Because of heterogeneity, the complexity of the network increases, and sometimes falsified results may appear.

Accessibility : For developing any farming decision support system based on IoT technology and other devices, the demand for availability of existing software and hardware to be present anywhere anytime is a must thing. These problems need to be addressed to ensure the availability of services anywhere and anytime. Lack of availability of the required equipment can result in chaos and delay in the services.

Energy optimization : Energy is the most emerging issue in IoT systems, WSNs, and other devices for their communication. Till now conventional sources of energy have been supporting the designing and working models. But due to an increase in devices, the consumption of conventional energy is not a reliable solution. Non-conventional sources of energy like solar, wind, water energy harvesting schemes should also be tested, but they haven't been of much success and new methodologies should be developed to employ them for model development.

Reliability : For successful and smooth working, reliability is a major concern for IoT devices in terms of data transmission. The devices need to gather and transfer reliable data as based on the data received and interpreted, the decisions are made. Reliability is still a challenge due to system failures, node failures, battery issues, or other interventions.

Adaptability : While designing a model, especially for precision farming, it is pertinent for the devices to be adaptable with the other devices and the surroundings. Since the environmental conditions keep varying and also sometimes due to certain communication or hardware issues certain devices are not adaptable with each other.

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Chapter 12

Millets : Nutricereals as Medicines and Value Addition

M. Shanthi Priya, L. Madhavilatha, B. Rupesh Kumar Reddy, M. Hemanth Kumar, N.V. Sarala, B. Vajantha and T.M. Hemalatha
ANGRAU-Agricultural Research Station, Perumallapalle, Tirupati-517 505, Andhra Pradesh

Introduction

Millets are a group of highly variable small seeded grasses, widely grown around the world as cereal crops or grains for fodder and human food. Millets manifest immense potential against climate change owing to their hardy nature and ability to withstand extreme temperatures, floods and droughts (Dayakar *et al.,* 2017). Millets can be used to achieve food security as well as nutritional security even in harsh adverse weather conditions. But over the last 30-40 years their use has come down drastically. The main reasons for this are the changes in people's eating habits, focus of farmers on commercial crops, lack of proper support price for millets and availability of food grains such as rice and wheat at low prices. Declaration of 2023 as the International Year of Millets has attracted the attention of world towards millets. Indian Government's initiative to encourage citizens for healthier diet to overcome the problem of malnutrition and draught, has led to the revival of millets in Indian market. Growing millets in changing climatic conditions can reduce the cost of cultivation and the use of harmful chemicals is also reduced as these crops are expected to be less infected with pests and diseases. Cultivation of millets, which are natural resources, should be increased to build a healthy society. Millets are rich in carbohydrates, proteins, vitamins, minerals, fatty acids, and fiber that are essential for our body structure and health. Millets help in prevention of chronic health problems such as high blood pressure, diabetes, obesity, heart disease, gastrointestinal diseases, and arthritis. Hence millets are named as nutri-cereals. Nine types of millets i.e., sorghum, bajra, ragi, korra, sama, aarika, variga, ooda and andukorra are being cultivated in India. The scientific names of millet crops along with chromosome number and ploidy levels were presented in Table-1.

Nutritional importance of millets

Millets are the important food and fodder crops and are predominantly gaining more importance due to their nutritional benefits and climate resilience. These crops are adapted to wide range of temperatures, moisture-regimes and input conditions supplying food and feed to millions of dry land farmers. Millets are the oldest cultivated grains in the world and have been grown throughout Africa and Southeast Asia for thousands of years. Millet can be used to make bread, beer, cereal, and other dishes. Even today, millet is a staple food around the world. In fact, millets are gaining renewed popularity because of their importance in nutritional security. Millets are rich in niacin, which is important for healthy skin and organ function. Millet, especially the darker varieties, are excellent sources of beta-carotene. This natural pigment acts as both an antioxidant and as a precursor to vitamin A, helping your body fight off free radicals and supports the health of eyes. Millets are low in simple carbohydrates and higher in complex carbohydrates, making it a low-glycemic index (GI) food. This means millet takes longer time to digest than wheat or rice. Low-GI foods can help keep your blood sugar from shooting up after eating, which allows people with diabetes to manage their blood sugar levels

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more easily. Millets are rich in dietary fibre, both soluble and insoluble. The insoluble fibre in millet is known as a “prebiotic,” which means it supports good bacteria in your digestive system. This type of fibre is also important for adding bulk to stools, which helps keep you regular and reduces your risk of colon cancer. The soluble fibre in millet can help reduce the amount of ‘‘bad’’ cholesterol in your blood a risk factor for atherosclerosis. Soluble fibre turns into a gel in your stomach and absorbs cholesterol, allowing it to be safely carried out of your system. Studies show that millet can also raise your “good” cholesterol levels and lower triglycerides. Because cholesterol is such a big risk factor for heart disease, eating millet regularly may help keep your heart healthier. Millet is rich in potassium, a mineral that supports healthy kindey and heart function. Potassium also plays a role in nerve signal transmission, which is how your brain and muscles communicate. Millets are excellent source of Vitamin A, Vitamin B, Phosphorus, Potassium, Antioxidants, Niacin, Calcium and Iron.

Earlier millets were considered as poor man’s food grains but in recent years millets became rich man’s food. Millets are rich in several beneficial nutrients, such as phosphorus, magnesium, copper, and manganese. Incorporation of millets in diet has the following benefits.

Weight Loss

The calorie content of millets is low, and they are an excellent food product for weight loss. Not just those looking to lose weight, it benefits people who are conscious of their fitness too. It helps them maintain their energy level throughout the day without having to eat to refuel themselves constantly. Millets also keep you satiated for longer than other carbohydrates. When you consume them, you feel fuller for longer as they take time to get digested and absorbed into your body that prevents overeating.

Lowers blood sugar level

Millets having a low glycemic index, consumption of millets reduces risk of developing diabetes.

Boosts Immunity

Protein intake is responsible for building the body’s immunity.

Millets provide a great source of protein and can help develop and strengthen our immunity.

Stronger immunity means fewer chances of you catching diseases.

Reduces Cardiovascular Risks

Millets contain essential fats, which provide our bodies with good fats which prevent excess fat storage as well as effectively lowers the risk of high cholesterol, strokes, and other heart complaints. The potassium content in millets regulates your blood pressure and optimises your circulatory system.

Prevents Asthma

The magnesium content in millets can reduce how frequently you experience migraines. It can also bring down the severity of your asthma complaints. The reason is, unlike wheat, they do not contain the allergens that lead to asthma and wheezing.

Helps in digestion

Millets are a rich fibre source that benefits digestion by alleviating bloating, gas, cramping, and constipation. In addition, good digestion keeps issues like gastric/colon cancer and kidney/liver complaints away.

Acts as an Antioxidant

Millets help your body detox because of their antioxidant properties; Quercetin, curcumin, ellagic acid, and other valuable catechins flush out toxins from your body and neutralise the enzymatic actions of your organs.

Nutrient composition of millets:

The main protein fraction of millets has high biological value, with good amounts of tryptophan, cystine, methionine, and total aromatic amino acids, which are all crucial to human health and growth and are deficient in most cereals. Small millets are highly nutritious and even superior to cereal crops like rice and wheat which is shown in Table-2.

Sorghum : It is rich source of carbohydrates, fats, niacin and proteins which makes it a very good food for people suffering from diabetes and obesity. The polyphenols and tannins present in sorghum have anti-mutagenic and anti-carcinogenic properties (Grimmer *et al.,* 1992). Sorghum is an important source of B vitamins except for vitamin B12 (Gazzaz *et al.,* 1989). Yellow coloured sorghum grain is rich in beta carotene, leutin and zeaxanthin. Sorghum is excellent source of polyphenols, flavonoids and condensed tannins which are antioxidant potent in nature.

Table-1 : Millet crops Scientific names and chromosome number.

S. No.	Common name	Botanical name	Chromosome number along with ploidy level
1.	Jowar (Sorghum/Jonna/Great millet)	*Sorghum bicolor* (L.) Moench.	2n=2x=20
2.	Bajra (Sajja/Ganti/Pearl millet/Bulrush millet / Cat tail millet)	*Pennisetum glaucum* L. (R. Br.)	2n=2x=14
3.	Ragi (Chodi/Thaida/Finger millet)	*Eleusine coaracana* L. Gaertn.	2n=4x=36 AABB
4.	Korra (Italian millet/Foxtail millet)	*Setaria italica* L.P. Beauv.	2n=2x=18
5.	Variga (Proso millet/common millet)	*Panicum miliaceum* L.	2n=4x=36 AABB
6.	Sama (Little millet)	*Panicum sumatrense* Roth.	2n=4x=36 AABB
7.	Arika (Kodo millet)	*Paspalum scrobiculatum* L.	2n=4x=40
8.	Ooda (Barn yard millet)	*Echinocloa colona* L.P. Beauv	2n=6x=54
9.	Andu korra (Browntop millet)	*Brachiaria ramosa* (L.) Stapf.)	2n=4x=16

Table-2 : Nutrient composition of millets and cereals (per 100g edible portion).

Cereals	Protein (g)	Fat (g)	Ash (g)	Crude fibre (g)	Carbohy drates (g)	Energy (kcal)	Calcium (mg)	Iron (mg)	Thiamin (mg)	Ribo-flavin (mg)	Niacin (mg)
Rice (brown)	7.9	2.7	1.3	1.0	76.0	362.0	33.0	1.8	0.4	0.0	4.3
Wheat	11.6	2.0	1.6	2.0	71.0	348.0	30.0	3.5	0.4	0.1	5.1
Maize	9.2	4.6	1.2	2.8	73.0	358.0	26.0	2.7	0.4	0.2	3.6
Sorghum	10.4	3.1	1.6	2.0	70.7	329.0	25.0	5.4	0.4	0.2	4.3
Pearl millet	11.8	4.8	2.2	2.3	67.0	363.0	42.0	11.0	0.4	0.2	2.8
Finger millet	7.7	1.5	2.6	3.6	72.6	336.0	350.0	3.9	0.4	0.2	1.1
Foxtail millet	11.2	4.0	3.3	6.7	63.2	351.0	31.0	2.8	0.6	0.1	3.2
Little millet	9.7	5.2	5.4	7.6	60.9	329.0	17.0	9.3	0.3	0.1	3.2
Kodo millet	9.8	3.6	3.3	5.2	66.6	353.0	35.0	1.7	0.2	0.1	2.0
Proso millet	12.5	3.5	3.1	5.2	63.8	364.0	8.0	2.9	0.4	0.3	4.5
Barnyard millet	11.0	3.9	4.5	13.6	55.0	300.0	22.0	18.6	0.3	0.1	4.2
Browntop millet	11.5	-	-	12.5	-	-	0.01	0.65	-	-	-

Bajra : It is incredibly nutrient-dense. Pearl Millet has the highest protein content. It contains many essential minerals like magnesium, phosphorus, zinc etc. It contains essential amino acids and vitamins also which contribute to its therapeutic properties. Bajra contains high percentage of iron and it helps in prevention of anemia in women and children. It gives energy to the body and nourishes the blood. Regular consumption of pearl millet helps to fight against type II diabetes.

Ragi : It contains higher levels of calcium than all food grains. The calcium in it is very essential for women and growing children, and beneficial for bone strength and dental nutrition. It is used as a healthier substitute for rice and wheat. Ragi is gluten-free and rich in B complex vitamins and proteins. Ragi malt is given as a supplement to breastfed babies as it is supposed to aid brain development in growing children. It is also a good source of essential amino acids like arginine, lysine, methionine, lecithin.

Korra : It contains high levels of all the nutrients the body needs to nourish itself. It contains blood sugar balancing healthy carbohydrates. The iron and calcium content present in it also helps strengthen immunity. In addition, foxtail millets help regulate blood cholesterol and increase HDL cholesterol levels in the body.

Sama : It is very good for those who use less oil. Replacement of rice with sama is an excellent option for those looking to lose weight. It is high in fibre and filled with numerous minerals such as potassium, zinc, iron, and calcium. It is also packed with the health benefits of vitamin B and works as an antioxidant for your body.

Aarika : It has high protein content (11%), low fat (4.2%) and very high fibre content (14.3%). It is very easy to digest; it contains a high amount of lecithin and is excellent for strengthening the nervous system. Aarika grains are rich in B vitamins, especially niacin, B6 and folic acid, as well as the minerals such as calcium, iron, potassium, magnesium and zinc. It contains no gluten and is good for people who are gluten intolerant. Regular consumption of kodo millet is very beneficial for postmenopausal women suffering from signs of cardiovascular disease, like high blood pressure and high cholesterol levels

Variga : It is rich in proteins, thiamin, riboflavin and niacin. The protein content was found to be (11.6% of dry matter) and was significantly rich in essential amino acids (leucine, isoleucine, and methionine) than wheat protein (Kalinova and Moudry, 2006). It is rich in vitamins and minerals such as copper and magnesium.

Ooda : It is high in iron and fiber. t is a good source of protein, which is highly digestible and is an excellent source of dietary fiber with good amount of solu ble and insoluble fractions. The carbohydrate content of barnyard millet is low and slowly digestible, which makes the barnyard millet a nature's gift for the modern mankind who is engaged in sedentary activities. In barnyard millet the major fatty acid is linoleic acid followed by palmitic and oleic acid. It also shows a high degree of retrogradation of amylase, which facilitates the formation of higher amounts of resistant starches. Hence it can be potentially recommended for the patients with cardiovascular disease and diabetes mellitus. Barnyard millet is most effective in reducing blood glucose and lipid levels.

Andukorra : It is rich in proteins and fibre. Contains essential nutrients, calcium, iron, phosphorus, potassium, magnesium, manganese, copper, sodium and zinc which helps for good health. Regular intake of this grain lowers the risk of heart diseases and diabetes.

Limitations in usage of millets

With the increasing availability of other cereals, minor millet consumption in Asia is getting restricted to the poorest of the poor in the semi-arid or mountainous regions, who cannot afford other grains and to those having traditional affinity.

With the increasing availability of other grains such as Rice, Wheat and Maize, who can afford these grains due to less processing.

Discouraging millet cultivation and consumption, due to change in the food habits of people or urbanization.

Drudgery associated with millets grain processing.

Difficulty in processing technology and non-availability of suitable machinery

The non-availability of ready to use processed millet has limited the usage and acceptability, despite their nutritional superiority.

Minor millets are largely consumed as traditional preparations.

Increasing urbanization and decreasing time for domestic chores in rural households are discouraging traditional processing of millets.

Value addition in millets

Several processing techniques have been developed to enhance food value and shelf-life of millet products and to improve the availability of starch, protein and minerals. Value addition techniques in millets are expected to generate consumer demand for millet based food products. In addition, value addition to minor millets not only offers variety, convenience and quality food to consumers, but also helps in revival of millet cultivation. Minor millets can be used for traditional as well as novel foods. However, there is a need to look into the possibilities of alternative uses. Value addition to food has assumed critical importance in the last decade due to socio-economic and industrial factors. Properly stored, whole millet can be kept safely for up to two years. The grain should be stored in tightly closed containers, preferably glass, in a cool dry place with a temperature of less than 70° or in the refrigerator. The flour deteriorates and becomes rancid very rapidly after it is ground, so it is best to grind the flour right before it is to be used. Germination, decortication, malting and fermentation enhance the nutritional value by reducing/eliminating anti-nutritional factors and imparts desirable flavour and taste. Shelf life of millet flour is also increased by malting as this lowers the levels of lipids that are responsible for off-flavors. Blanching and heat treatment improve the storability and stability of flour. Most of the millets can blend very easily with common staple foods without any pronounced off flavors. They have mighty potential to be included in traditional and novel foods. There is a need to provide millet based food products in the form of ready to use grains, convenience foods or mixes to meet the demands of the present day consumers.

Because of the high nutritional quality the usage of millets grain in various forms is on the increase and now government of India is also giving focus to encourage farmers to grow millet crops through special schemes. Though the country is self-sufficient in food grain production and combating under nutrition, the threat of mal nutrition is still conspicuous and need to be targeted to build a strong nation for which millets offer right solution.

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Chapter 13

Genetically Modified Cotton

Ram Naresh[1*], S.P. Singh[2], Vikas Teotia[3], Ragini Dubey[4], Yatendra Singh[5], Nikhil Vikram Singh[1] and Harish Pal Bhati[6]

[1]*ICAR-Agricultural Technology Application Research Institute, Zone–III, Kanpur, Uttar Pradesh*
[2]*CSAUAT–Agriculture Research Station, Kalai, Aligarh, Uttar Pradesh*
[3]*Department of Agronomy, C.S.A. University of Agriculture and Technology, Kanpur Uttar Pradesh*
[4]*Department of Family Resource Management, C.S.A. University of Agriculture and Technology, Kanpur Uttar Pradesh*
[5]*Monad University, Hapur, Uttar Pradesh*
[6]*Government College (CCS University, Meerut) Jewar, G.B. Nagar, Uttar Pradesh*
Email : rngurjar9@gmailcom

Introduction

The most significant commercial crop in our nation, cotton contributes up to 75% of the entire raw material requirements of the textile sector and employs about 60 million people. India has the greatest area under cotton production, but its productivity is very low, mostly because so much of it is grown using a rain-fed system with insufficient inputs. India leads the world in terms of land area, but China is its closest competitor when it comes to production. All four of the *Gossypium* species that produce spinnablefibers *Gossypium hirsutum, G. barbadense, G. arboreum*, and *G. herbaceum* are grown commercially only in India. In the Indian cotton industry, hybrid cotton farming accounts for around 45% of the total cotton acreage and contributes about 55% of production.

India's cotton production has changed both qualitatively and quantitatively since independence. Short and medium staple cottons were the most common types produced at the time of independence. India currently produces the broadest variety of cottons, from coarse, non-spinnable cotton to medium, long, extra-long, and superfine cotton, in counts ranging from 6 to 120. During the previous ten years, cotton productivity peaked at roughly 300-330 kg of lint per hectare, but over the last two years, it has increased to more than 460 kg.

Several insect pests target cotton, which significantly lowers crop productivity. The insect pests that attack cotton crops can be categorised as either chewing insects or sap sucking insects (Aphids, Jassids, and White flies) (Bollworms, leaf eating caterpillars etc.). Approximately 45% of all pesticides used in Indian agriculture are sprayed on cotton crops alone. Several tactics, including the use of genetic resistance to insect pests, integrated pest management (IPM), insecticide resistance management (IRM), etc., are encouraged to reduce the use of pesticides in cotton. The best method now available for controlling bollworms, the most significant pest of cotton, is Bt cotton technology.

Benefit of Bt. cotton

Using long-term data on Bt cotton effects across India, more recent research has revealed that Bt cotton does not provide Indian farmers with any long-lasting advantages. According to the research, Bt cotton has little influence on cotton yield, and although it may have initially reduced the usage of insecticides, this effect is now waning as a result of bug populations that are resistant to insecticides. The methodologies used in this study, however, have weaknesses that render the findings untrustworthy and call for additional research on the consequences of Bt cotton.

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Existing research on the effects of Bt cotton has some significant gaps. For instance, rather than focusing on the state level, a large portion of current research examines the consequences of Bt cotton at the national level. Since there are known variations in the production of Bt cotton throughout Indian states, this is a concern. Furthermore, current research frequently examines Bt cotton output averages across several years or contrasts two distinct time points. These methods prevent us from identifying significant yearly variations in the effects of Bt cotton.

Chronology of Bt. Cotton in India

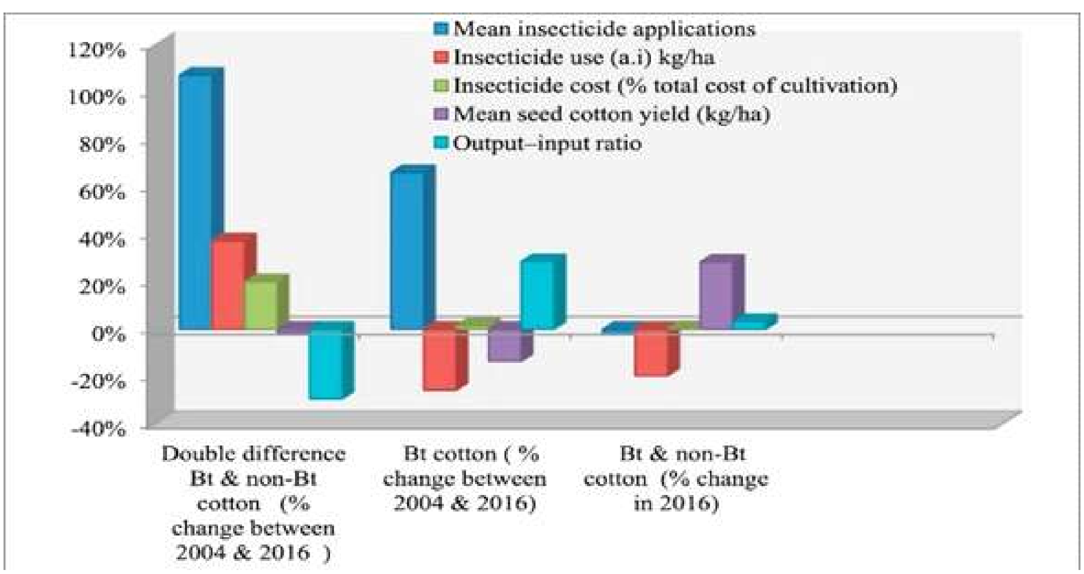
Since it supports more than 60 million people's livelihoods through support for agriculture, processing, and use of cotton in textiles, cotton, often known as the "White Gold," is a significant cash crop in India and a crucial component of the Indian economy. It is grown on an area of roughly 9.5 million hectares, which is nearly one-fourth of the 35 million hectares of cotton planted worldwide. India has overtaken China as the world's second-largest cotton consumer and producer despite having low productivity. The introduction of Bt cotton in 2002 is responsible for India's enormous increase in cotton production over the past ten years. On March 26, 2002, the first genetically modified (GM) crop in India, CBt cotton1, received first approval for commercial planting in six states located in the southern and central cotton-growing regions of the nation. Insect pests like *Helicoverpa armigera*, often known as the American Bollworm, which formerly caused significant crop damage and low production, were the impetus for the introduction of Bt cotton. Therefore, Bt cotton technology was introduced into India by Mahyco (Maharashtra Hybrid Seed Company), working with Monsanto. The Bacillus thuringiensis var. common soil bacterium's Cry1Ac gene is present in Bt cotton. The production of the Cry1Ac protein, which imparts resistance to the bollworm complex, is brought about by kurstaki. The use of insecticides has decreased thanks to the superior control that Bt cotton hybrids2 have shown over the American Bollworm. This has enabled the creation of eco-friendly environments without sacrificing productive output. Bt cotton has decreased agricultural risk and enhanced farmers' perspectives on growing cotton crops, in addition to lowering production costs and improving profit. The top three cotton producing states are Maharashtra, Gujarat, and Andhra Pradesh, and Bt cotton accounts for 88.44 percent of the total area of 111.42 lakh hectares under cotton production, according to the most recent statistics given by the Union Agriculture Ministry for the year 2010–2011.

On March 10, 1995, Mahyco was granted permission by the Indian government's Department of Biotechnology (DBT) to import 100 gm of transgenic Cocker-312 cottonseed. The Bacillus thuringiensis gene Cry 1 Ac was present in this variant.

Monsanto and Mahyco join forces in April 1998. Department of Biotechnology grants Monsanto licence for 100 g per trial Bt cotton trials (DBT).

January 8, 1999: RCGM declares satisfaction with the trial outcomes at 40 locations and orders MAHYCO to submit trial application requests to MEC by April 12 for 10 locations. ICAR trials were conducted between 2000 and 2002 at various AICCIP centres in the Central and South Zones.

On February 20, 2002, the Ministry of Environment receives a favourable report from the



Indian Council of Agricultural Research (ICAR) regarding the field tests of Bt cotton. It is now anticipated that the Environment Ministry's Genetic Engineering and Approval Committee (GEAC) will approve the commercial usage of Bt cotton within a month. On March 25, 2002, GEAC authorised the commercial cultivation of three Bt Cotton hybrids produced by M/s. MAHYCO.

In India, the amount of land planted with the Bt cotton hybrid has grown from just 29,307 ha in 2002 to 12,50,833 ha in 2005. As predicted by the seed business, the area expanded to 30,00,000 acres in 2006. Table 2 provides a state-by-state breakdown of the area covered by Bt hybrids. Approximately 100 lakh acres, or 40% of the total area planted with cotton hybrids, may possibly be planted with the Bt variety, producing 40 lakh packages annually worth Rs. 640 crore. 52 distinct Bt cotton hybrids have thus far been made available for cultivation in India.

Climatic Requirements

Soils **:** Around the world, cotton is grown on a range of soil types. Cotton is best grown in deep, fertile soil that has a sufficient amount of humus, a high water holding capacity, and good internal drainage. Cotton is delicate to high levels of humidity and water logging.

It is typically planted in rainfed environments on soils with high water holding capacities, which improve internal drainage and increase yield. It is grown on a range of soil types, from sandy to sandy loam and clay weaves, where irrigation is available. Because cotton is a deeply rooted crop, soil depths of less than 60 cm are not ideal. A pH of 7.0 to 8.0 is regarded as ideal, and neutral to slightly alkaline soils are excellent for cotton growth. For successful cotton growing, a pH of 5.3 is required. Only while the crop is germinating and early in its establishment is cotton vulnerable to salinity.

An established crop has a threshold E.C. of 7.7 ds/m and has a 50% yield drop at 17.7 ds/m E.C.

The main soil types in India for growing cotton are red (Alfisols), alluvial (Inceptisols), mixed red and black soil, and sandy to sandy looms (Entisols and Inceptisols) in the northern zone, black soils (vertisols) in the centre, and sandy to sandy looms (Entisols and Inceptisols) in the southern zone.

Temperature : Wherever there are at least 180 to 200 frost-free days, cotton can be cultivated. 20–30^{o}C is the ideal temperature for germination. If the temperature is below 180C, germination will be delayed.

A mean daily temperature of 21–27^{o}C is ideal for vegetative growth. The development of fruit and bolls is favoured by chilly nights and daytime temperatures between 27 and 32^{o}C. When the minimum temperature drops below 15^{o}C, cotton plant growth and fiber formation are severely constrained. The ideal temperature for peak flowering is between 29 and 34^{o}C. Cotton can endure short-term exposure to high temperatures of 43–45^{o}C in conditions with sufficient soil moisture.

Rainfall : Being a tropical plant with an arid origin, cotton needs at least 500 mm of mean annual rainfall that is evenly distributed. Moderate rainfall is beneficial during the vegetative phase, but severe rains will degrade cotton quality later on.

Its growth is favoured by nighttime rain and daylight. The shedding of buds and bolls is accentuated by heavy rainfall or moisture stress during flowering and fruiting. Fungus infection is caused by high atmospheric humidity. Good quality lint is ensured by a dry period during the ripening and boll bursting periods.

Bt. Cotton Verities

Sl. No.	Trade Name	Producers
1.	Ashirvad	Dhanya
2.	Ajeet-ACH199	Ajeet
3.	Denim	Pravardhan
4.	*Jaddoo*	Kaveri
5.	Rasi 659	Rasi
6.	MRC 7373	Mahyco
7.	US 81	Seed Works
8.	Navneeth	Nuziveedu
9.	Yadhuveer	Bioseed
10.	CCH 999	Crystal

Fertilizers

A minimum of once every three years, a cotton crop should be manured with FYM or compost at a rate of 12 to 15 tons/ha.

For irrigated cotton, the recommended fertiliser dose is 100:50:50 (NPK) kg/ha; for rainfed cotton hybrids, 80:40:40 (NPK) kg/ha; and for both desi and hirsutum types, 50:25:25 (NPK) kg/ha. For rainfed cotton crops, nitrogen should be applied twice: 50% at sowing time and 50% at the square formation stage. For irrigated cotton crops, nitrogen should be applied three times: 1/3 at sowing time, 1/3 at one month after sowing, and the last 1/3 at 60 DAS. While full P and K ought to be used as a basal dose for both cotton grown under irrigation and in the rain.

When planting cotton using the ring method, the basal dose of fertilizer should be applied 5 to 6 cm distant from the seed that has been dug up. Delay in applying the recommended amount of fertilizer affects the yield of seed cotton by 10% to 40% over the course of 10 to 30 DAS.

Spraying DAP at a rate of 2% during the blooming and boll development stages increased seed cotton output by 10 to 20% and prevented cotton from being shredded.

Azatobactor seed treatment was found to be beneficial for cotton crops, lowering the nitrogen dose by 20 to 25%.

Water Requirements

Farmers thoroughly water the fields prior to sowing in regions without adequate winter rainfalls. Most of the time, farmers do not irrigate frequently between sowing and blossoming. Cotton growers start irrigating more frequently after the plants bloom, every 5-7 days, depending on other factors. The cotton boll spontaneously splits open along the segments of the boll and starts to dry out 45 days after sowing, or 140 days later. For the cotton to dry out more quickly during that time (usually in the late summer), many farmers halt irrigation (or only gently irrigate once every two weeks). The majority of cotton fields employ drip irrigation, but there are alternative techniques as well (flooding, centre pivots, etc.).

Weed Management

Long before any seeds are sown, the initial tillage is performed in order to combat weeds. Farmers then frequently spray with different pesticides until the plants are well-established, taking into account the texture of each field and the weeds that are most frequently present in each location (ask a licenced agronomist in your area). The regular tillage of the area between the plant rows is a crucial step towards good weed management. The farmer must be careful not to damage any of the cotton plant's parts while they execute the tillage because this distance varies from 2 to 4 feet. When the space in between the planting rows is ploughed, weeds that have just emerged are killed, and the field's aeration is improved. Farmers frequently plough once or twice a month during active growth and perform the last tillage after flowering in places where no modern broad spectrum herbicides are employed.

Cotton field weeds can be efficiently eliminated ort By using an appropriate pesticide during the germination stage, their growth can be reduced. They can provide a significantly better weed-free environment for the crop in its early stages. The early weed control provided by pre-emergence application of pendimethalin and oxyflurofen will enable efficient use of the farmers' inputs. Herbicides like quizalofop-ethyl and pyrithiobac-sodium can be applied post-emergence to control weeds (both annual and perennial) that arise in the latter stages of crop growth. Herbicides would so effectively and affordably eliminate the weed problem.

Insect pest and disease

Management of cotton crop particularly pest and disease vulnerability by deploying appropriate technology & management practices.162 different species of insect pests attack various stages of cotton in India. About a dozen of these are significant, and half of them are important production restrictions that demand management interventions in the crop ecosystem. The widespread and fairly dangerous sucking pest complex, which includes aphids, jassids, thrips, and whiteflies. However, the current methods of cultural, chemical, biological, and host resistance mechanisms can effectively restrict their damage. The most significant and harmful tissue eaters are the bollworms. The three bollworm species known as the "bollworm complex"—American bollworm (Helicoverpa armigera), Pink bollworm (Pectionphora gossypiella), and Spotted bollworm (Eariasvitella)—are by far the most destructive and cost-inducing pests of cotton. Helicoverpa stood out among them as a significant pestall over the nation, inflicting up to 80% losses in cotton.

Status of Insect Pests and Diseases

Andhra Pradesh : Major Pest like jassid and pink bollworm.

Tamilnadu : No major Problem.

Gujarat : Persistent problem of pink bollworm.

Maharastra : Sporadic problem of pink bollworm in marathawada region from 2015-16

Telangana : Jassids , Pink bollworm and leaf reddening.

Punjab, Haryana and Rajasthan: severe infestation of whitefly and CLCV.

Management of Pink bollworm

Crop rotation to break the life cycle of the pest. Timely sowings. Planting non Bt. refugia around the field. Surveillance of Pink Boll Worm. Mass trapping

Sr.	Particulars	RDF NPK ($kgha^{-1}$)	Time of Application	Method of Application
I	Hybrids Irrigated	100:50:50	1/3rd N and full P_2O_5 and K_2O as basal, 1/3 rd N after 60 DAE	Ring method / Spot application
II	Rainfed	50:25:25	1/2nd N and full P_2O_5 and K_2O as basal, 1/2 nd N after 30 DAE	Ring method / Spot application
B	Improve varieties of Hrisutum	50:25:0	1/2 N and full P_2O_5 as basal, 1/2 N after 30 DAE	Broadcasting followed by hoeing
C	Improved varieties of arboretum	30:15:0	1/2 N and full P_2O_5 as basal, 1/2 N after 30 DAE	Broadcasting followed by hoeing
D	Arboretum hybrids	50:25:25	1/2 N and full P_2O_5 and K_2O as basal, 1/2 N after 30 DAE	Ring method / Spot application

and mating disruption technique on wide area through integrated approach. Release bio-agents and conserve natural enemies. Apply only CIB&RC recommended pesticides.

Management of Pink Bollworm (Off season)

Gin Sanitation. Field sanitation. Allow cattle, sheep and goats to graze. Removal and destruction of cotton stubbles. Create awareness on the importance of destroying pink bollworm damaged cotton seeds after ginning. Destroy trashed and stained cotton with damaged seeds whether lying in the farmer's house or in the Gins.

Management of whitefly and leaf curl virus

Regular awareness and trainings to the farmers. Removal of alternate hosts viz. vegetables, ornamentals and weeds. Use recommended hybrids/ varieties. Complete sowing before 15th May. Promote Desi cotton varieties. Apply recommended dose of fertilizers (avoid excessive use of urea) Plant barrier crops viz. sorghum/bajra/maize use yellow sticky traps. Avoid synthetic pyrethroids and tank mixing of pesticides.

State Specific Strategies Planned for Kharif

Maharashtra : Pink Bollworm is to be incorporated in **CROPSAP** Model for regular crop advisories. Short Duration Bt Hybrids/Varieties to be advised.

Gujarat : Awareness for cultivation of short duration varieties/Hybrids. Seed Companies to be involved for management of pink bollworm and training programmes. Supply of bio-agents and adoption of management advisories.

Andhra Pradesh and Telangana : Plan for diversification of cotton towards pulses and millets. Application of need based micro-nutrients for management of leaf reddening.

Cotton harvested in India

In India cotton picking is done by hand picking. But there is higher percentage of trash content. Picking of cotton should be done in the morning because due to humidity there is no sticking of dried leaves and other trash. First picking of cotton should be done when 30-35% bolls open fully. Picking should be done early in the morning. Due to humidity picking of cotton is easy and there is no sticking of dried leaves, and other contamination. At the time of picking cotton should be kept separately according grading that is clean and without contaminated cotton, yellowish cotton and defected cotton which is not fully open. Second picking should be done 15-20 days after first picking. At the time of picking first pick clean cotton and then affected cotton. It should be picked separately of different varieties. After picking it should be dried 3-4 days in sun with due care. Cotton should be stored at clean and dry place.

Yield

Indian farmers are sophisticated value-determinators. On average, Bt cotton seeds gave cotton growers yields of 700–900 kg per acre compared to 300–400 kg per acre with conventional seeds. Value is decided by farmers based on production quality, fair price, and convenience.

Year	Area in lakh hectares	Production in lakh bales	yield per hectare
2020-21	132.85	352.48	451
2021-22*(P)	119.10	312.03	445
2022-23*(P)	125.10	341.91	465

Source : Committee on cotton Production and Consumption (COCPc) in its meeting held on 15.11.2022, P-Provisional.

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Chapter 14

Knowledge of Fig Growers about Fig Cultivation Practices

Pramod S. Bankar, Pallavi D. Suryawanshi* and Tai B. Deokate
College of Agriculture, Pune-411005 Maharashtra
**Email : pallavidsextension@gmail.com*

Abstract

In India, Fig is considered to be a minor fruit crop. It is mostly confined to Western Parts of Maharashtra, Karnataka and Andhra Pradesh. Poona fig variety is mostly cultivated and prevailed in Purandar tehsil of Pune district. It's having commercial value, is very popular among the farmers. Numbers of factor are responsible for limiting the area and production of fig crop in Maharashtra state. The average yield of fig fruits and the area under cultivation is comparatively less. The present study was undertaken in Purandar tehsil of Pune district with sample size of 115 respondent farmers. The variables viz. age, education, experience, trainings attended, cosmopoliteness, sources of information, social participation, annual income, land holding, marketing price of pesticides, occupation and scientific orientation were studied. The study revealed that 62.00 percent of the respondent farmers had medium level of knowledge towards fig production technology.

Key words : *Fig, fig production technology, knowledge, farmers.*

Introduction

India is the second larger producer of fruits after China. It contributes about 8.57 per cent of the World's total produce of fruits. Horticulture plays a vital role in export and import substitution. Extension agencies are engaged in various sectors of the community development movement in the country. They work for making the farmer to adopt the recommendation of the scientists in improved farming. The adopters of improved practices of fig cultivation also differ much in adoption behavior.

The large quantity of dried fig is imported every year from Afghanistan and Greece to India. In India Fig is considered to be a minor fruit crop. It is mostly confined to Western Parts of Maharashtra, Karnataka and Andhra Pradesh. In Maharashtra, fig is cultivated in Western Maharashtra on a large scale. Pune district especially Purandar tehsil is the only area where it is cultivated on a commercial scale where Poona fig variety is mostly cultivated.

Number of factors are responsible for limiting the area and production of fig crop in Maharashtra state. The average yield of fig fruits and the area under cultivation is comparatively less. This is because of an extension cum resource gap. Considering this, the study was undertaken with objectives like to study the profile of the fig growers, the knowledge of fig growers about fig production technology and study the constraints.

Materials and Methods

Purandar Tehsil of Pune district was selected for the present study. Ten major fig growing villages and 115 fig growers were selected with the criterion that respondents should have fig orchard at least not less than of five years. Ex-post facto research design was used for the study.

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Results and Discussion

It could be stated from the above findings that majority of the respondent farmers were found in middle (46.97 per cent) and old (27.82 per cent) aged group. It is also observed that, more than half (52.18 per cent) of the respondents acquired secondary education followed by 20.86 per cent of the respondents had completed higher secondary education, whereas 13.04 per cent of the respondents had completed graduation and post-graduation and 12.18 per cent of the respondents had completed primary education while only two (1.37 per cent) respondents were found illiterate.

It can be observed from table that, 69.56 per cent respondent had medium fig cultivation experience while 17.39 per cent and 13.91 per cent had low and high level of fig cultivation experience respectively whereas 42.60 per cent of the fig growers had 0.21 to 0.40 ha of land under fig cultivation followed by 38.26 per cent of the fig growers having land (up to 0.20 ha) under fig cultivation. However, nine farmers (7.82 per cent) had land in between 0.41 to 0.60 ha, while seven (6.08 per cent) and six number (5.21 per cent) of farmers had land 0.81 ha and above and 0.61 to 0.80 ha respectively under fig cultivation.

It can be seen from table that, 81.73 per cent of the respondents had annual income up to Rs. 2.0 lakh from fig cultivation followed by 17.39 per cent of the respondents whose annual income from fig was in between 2.01 to 4.0 lakh. While only one farmer (0.86 per cent) had annual income from fig was in between Rs. 4.01 lakh to Rs. 6.0 lakh.

The table also depicts that, 61.73 per cent of the respondents had used medium source of information while 20.86 per cent of them had used high level and only twenty (17.39 per cent) respondents belonged to high level sources of information while almost equal i.e. 34.78 per cent and 33.91 per cent of the respondents had high and low level of social participation respectively. Only 31.30 per cent respondents had medium level of social participation.

The data in table 2 revealed the knowledge level of specific cultivation practices of fig as follows.

It can be observed from the table that, the majority (78.26 per cent) of respondents had complete knowledge about shallow to medium with well-drained soil is required for fig cultivation while 82.60 per cent of respondents had complete knowledge about fig should be cultivated in sub-tropical region.

It was also revealed that, the majority (69.56 per cent) of the respondents had complete knowledge about required temperature for cultivation of fig orchard while 52.17 per cent of respondents had complete knowledge about the recommended distance between two trees. It was noticed that 59.13 per cent of respondents had complete knowledge about pit filled with dry leaves, shell and plant parts etc. more than three-fourth (78.26 per cent) of respondents had complete knowledge about fig should be cultivated in January month.

It was revealed that, cent per cent (100.00 per cent) of respondents had complete knowledge about Poona fig variety, while varieties like Dinkar, Konadriya, Excel varieties are not known to farmers.

It was revealed that each 43.47 per cent of respondents had complete and partial knowledge about dose of organic fertilizer while more than half (52.17 per cent) of respondents had complete knowledge about 500 gm nitrogen fertilizer dose, while 60.86 per cent and 34.78 per cent of respondents had complete knowledge about each 150 gm phosprous and potash fertilzer dose / tree at the time of cultivation respectively. It was also seen that 34.78 per cent of respondents had complete knowledge about 1 kg neem cake/ tree should be applied at the time of cultivation. About half (47.82 per cent) of respondents had complete knowledge regarding organic fertilizer 50 kg / tree / year to the fully grown tree. More than three-forth (77.39 per cent) of the respondents had complete knowledge about 900 gm nitrogen should be supplied in the splits to the fully grown tree, while 70.43 per cent and 73.91 per cent of respondents had complete knowledge about 250 gm phosprous and 275 gm potash fertilizer/tree/year should be applied to the fully grown tree respectively.

It was revealed that, more than half (57.39 per cent) of the respondents had partial knowledge about water stress should be given after harvesting and water interval to be maintained. It was revealed that, cent percent (100.00) of the respondents had complete knowledge about *Khatta bahar* should be taken in rainy season and *Meetha bahar* in summer season and also about intercrop of fig orchard is spinach, tomato, cowpea, fenugreek and marigold.

It was revealed that, more than half of respondents had complete knowledge about pruning time for both the *bahars* while 55.65 per cent of respondents had partial knowledge about spraying of Dormax chemical without prunning should be done. It was also revealed that, each 60.86 per cent of respondents had full

Table-1 : Distribution of respondent farmers according to their personal, socio-economical characteristics.

Sr. No.	Particulars	Respondents (n=115)	
		Frequency	Per Cent
A	**Age**		
1	Young (up to 35 years)	29	25.21
2	Middle (36 to 55 years)	54	46.97
3	Old (56 & above years)	32	27.82
B	**Education**		
1.	Illiterate (no formal schooling)	02	1.73
2.	Primary school (1st to 7th std.)	14	12.18
3.	Secondary school (8st to 10th std.)	60	52.18
4.	Higher secondary school (11th and 12th std.)	24	20.86
5.	Graduation & Post graduation	15	13.04
C	**Experience in Fig Cultivation**		
1.	Low (Up to 10)	20	17.39
2.	Medium (11 to 20)	80	69.56
3.	High (21 and above)	16	13.91
D	**Area under Fig Cultivation (ha.)**		
1.	Up to 0.20	44	38.26
2.	0.21 to 0.40	49	42.60
3.	0.41 to 0.60	9	7.82
4.	0.61 to 0.80	6	5.21
5.	0.81 and above	7	6.08
E	**Income from Fig Production (Rs.)**		
1.	Up to Rs. 2.0 lakh	94	81.73
2.	Rs. 2.01 lakh to Rs. 4.0 lakh	20	17.39
3.	Rs. 4.01 lakh to Rs. 6.0 lakh	01	0.86
F	**Sources of Information**		
1.	Low (Up to 8)	20	17.39
2.	Medium (9 to18)	71	61.73
3.	High (19 and above)	24	20.86
G	**Social Participation**		
1.	Low (Up to 0.15)	40	34.78
2.	Medium (0.16 to 1.85)	36	31.30
3.	High (1.86 and above)	39	33.91

knowledge of both leaving one stem and many stem at training time.

It was revealed that, more than half (52.17 per cent) of the respondents had complete knowledge about digging of farm should be done in the month of July or August while 65.21 per cent of respondents had complete knowledge about farm digging should be done from month of January to March. More than half 52.17 per cent of the respondents had full knowledge about farm pulverisation should be done when fruits become of arecanut size.

It was revealed that, 52.17 per cent of respondents had full knowledge about pest control of stem borer should be done by soaking the cotton with the mixture of Carbon Di-sulphide and Chloroform liquid to fill the stem hole while 57.39 per cent of respondents had full knowledge about to put some drops of Nuvon chemical in the hole then wipe it with mud to control the stem borer. It was revealed that, 56.52 per cent of respondents had complete knowledge about collection and destruction of affected leaves while 60.86 per cent of respondents had complete knowledge about spraying of Dimethoate or Metasystox 0.05 per cent / lit water if area is highly affected to control the leaf roller. Nearly half of the (49.57 per cent) of the respondents had complete knowledge about spraying

Table-2 : Distribution of the respondents according to their knowledge level of cultivation practices of fig.

Sr. No.	Fig Cultivation Practices	Knowledge (n=115)			Total
		Complete	Partial	No	
1.	**Land-Shallow to medium with well-drained soil**	90 (78.26)	20 (17.39)	5 (04.35)	115 (100.00)
2.	**Environment**				
1	Fig is cultivated in sub-tropical region	95 (82.60)	15 (13.04)	5 (04.35)	115 (100.00)
2	Temperature in between 240c to 37.50c	80 (69.56)	00 (00.00)	35 (30.44)	115 (100.00)
3.	**Pit size and Distance**				
a.	Distance betn two trees –4.5 m × 3 m.	60 (52.17)	40 (34.78)	15 (13.04)	115 (100.00)
b.	Pit size - 90 cm × 90 cm × 90 cm.	60 (52.17)	54 (46.95)	1 (00.86)	115 (100.00)
c.	Pit filled with dry leaves, shell and plant parts etc.	68 (59.13)	00 (00.00)	47 (40.86)	115 (100.00)
d.	Fig is cultivated in January month.	90 (78.26)	25 (21.73)	00 (00.00)	115 (100.00)
4.	**Fig Variety**				
1.	Poona Fig	115 (100.00)	00 (00.00)	00 (00.00)	115 (100.00)
5.	**Fertilizer Dose**				
	1. At the time of cultivation				
a.	**Organic fertilizer - 10 kg / tree**	50 (43.47)	50 (43.47)	15 (13.05)	115 (100.00)
b.	**Chemical fertilzer / tree-**				
1.	500 gm Nitrogen	60 (52.17)	50 (43.47)	05 (04.34)	115 (100.00)
2.	150 gm Phosprous	70 (60.86)	40 (34.78)	05 (04.34)	115 (100.00)
3.	150 gm Potash	70 (60.86)	40 (34.78)	05 (04.34)	115 (100.00)
c.	**Other fertilzer / tree - 1kg Neem Cake**	40 (34.78)	40 (34.78)	35 (30.43)	115 (100.00)
	2. Full grown tree				
a.	**Organic fertilizer- 50 kg / tree / year**	55 (47.82)	45 (39.13)	15 (13.04)	115 (100.00)
b.	**Chemical fertilzer / tree /year**				
1.	900 gm Nitrogen (split doses i.e into September and November end)	89 (77.39)	26 (22.60)	00 (00.00)	115 (100.00)
2.	250 gm Phosprous	81 (70.43)	34 (29.56)	00 (00.00)	115 (100.00)
3.	275 gm Potash	85 (73.91)	30 (26.08)	00 (00.00)	115 (100.00)
6.	**Irrigation Interval**				
1.	Water stress up to July /August	45 (39.13)	66 (57.39)	04 (03.47)	115 (100.00)
2.	Water interval in the month of October to November is 8-10 days	36 (31.30)	71 (61.73)	08 (06.95)	115 (100.00)
3.	Water interval in the month of December to February is 12-14 days	41 (35.65)	59 (51.30)	15 (13.04)	115 (100.00)
4.	Water interval in the month of March to May is 7-12 days	47 (40.86)	63 (54.78)	05 (04.34)	115 (100.00)
5.	Water stress after harvesting	55 (47.82)	60 (52.17)	00 (00.00)	115 (100.00)
7.	**Bahar**				
1.	Khatta bahar in rainy season	115 (100.00)	00 (00.00)	00 (00.00)	115 (100.00)
2.	Meetha bahar in summer season	115 (100.00)	00 (00.00)	00 (00.00)	115 (100.00)
8.	**Intercropping-** Spinach, Tomato, Cowpea, Methi, Marigold etc.	115 (100.00)	00 (00.00)	00 (00.00)	115 (100.00)
9.	**Training and Prunning**				
a.	Prunning				
1.	From 15 May to 15 June	70 (60.86)	00 (00.00)	45 (39.14)	115 (100.00)
2.	From 15 August to 15 September	68 (59.13)	00 (00.00)	47 (40.86)	115 (100.00)
3.	Spraying of Dormax chemical without prunning (Hydrogen Cynamide in 20 ml / lit Water) 100 ml/ tree	64 (55.65)	00 (00.00)	51 (44.34)	115 (100.00)
b.	**Training**				
1.	Leave one stem	70 (60.86)	00 (00.00)	45 (39.14)	115 (100.00)
2.	Leave many stem	70 (60.86)	00 (00.00)	45 (39.14)	115 (100.00)

Contd...

Table-2 : Contd....

Sr. No.	Fig Cultivation Practices	Knowledge (n=115)			Total
		Complete	Partial	No	
10.	**Farm digging and farm pulverisation**				
a.	**Farm digging**				
1.	From July to August	60 (52.17)	00 (00.00)	55 (47.83)	115 (100.00)
2.	From January to March	75 (65.21)	00 (00.00)	40 (34.79)	115 (100.00)
b.	**Farm pulverisation when fruits become arecanut size**	60 (52.17)	00 (00.00)	55 (47.83)	115 (100.00)
11.	**Protection of orchard from birds**				
1.	Harvesting of fig at morning from 7 to 8	95 (82.60)	00 (00.00)	20 (17.40)	115 (100.00)
2.	Gradding of fig in orchard at afternoon	66 (57.39)	00 (00.00)	49 (42.61)	115 (100.00)
12.	**Pest control**				
a.	**Stem borer control measure**				
1.	Soak the cotton with the mixture of Carbon Di-sulphide and Chloroform liquid to fill the stem hole.	60 (52.17)	00 (00.00)	55 (47.83)	115 (100.00)
2.	Put some drops of Nuvon chemical in the hole then wipe it with mud.	66 (57.39)	00 (00.00)	49 (42.61)	115 (100.00)
b.	**Leaf roller control measure**				
1.	Collection and destruction of affected leaves.	65 (56.52)	00 (00.00)	50 (43.48)	115 (100.00)
2.	If area is highly affected Dimethoate or Metasystox 2ml / lit water spray	70 (60.86)	00 (00.00)	45 (39.14)	115 (100.00)
c.	**Thrips control measure**				
1.	Spray 7.5 per cent Acifate 0.15 per cent (2 ml)/ lit water.	57 (49.57)	00 (00.00)	58 (50.43)	115 (100.00)
d.	**Spider control measure**				
1.	Spray 1.5 ml Dicofol or 0.5 ml Vertimax / lit. water	45 (39.13)	35 (30.43)	35 (30.43)	115 (100.00)
e.	**Wooly aphid control measure**				
1.	Spray Lannete 2 gm / lit water	35 (30.43)	65 (56.52)	15 (13.04)	115 (100.00)
13.	**Disease Control**				
a.	**Wilt control measure**				
1.	Collect and destruct the affected leaves in summer	80 (69.56)	00 (00.00)	35 (30.43)	115 (100.00)
2.	Spray Plantavax 2 ml + 1 gm Carbondenzim / lit. water betn 10 days interval	50 (43.47)	56 (48.69)	09 (7.84)	115 (100.00)

Table-3 : Distribution of the respondents according to their overall knowledge level.

Sr. No.	Knowledge level (Score)	Respondents (n=120)	
		Frequency	Per Cent
1.	Low (Up to 60)	13	11.30
2.	Medium (61 to 83)	72	62.60
3.	High (84 and above)	30	26.08

of Acifate 0.15 per cent (2 ml) / lit water to control the thrips. It was revealed that, the 39.13 per cent of respondents had complete knowledge about spraying of 1.5 ml Dicofol or 0.5 ml Vertimax / lit water to control the spider. Only 30.43 per cent of respondents had complete knowledge about spraying of Lannete 2 gm / lit water to control the wooly aphid.

It was revealed that, 69.56 per cent of respondents had complete knowledge while 30.43 per cent of respondents had no knowledge about method of collection and destruction of the affected leaves in summer. About half (48.69 per cent) and 43.47 per cent of the respondents had partial knowledge and complete knowledge respectively about spray Plantavax 2 ml. +

1 gm. Carbondenzim / lit water between 10 days interval to control the wilt.

It was observed from the study that, 62.60 per cent of the respondent had medium level knowledge of recommended fig cultivation practices, while 26.08 per cent of the respondent had high level of knowledge and 11.30 per cent of the respondent had low level of knowledge about recommended cultivation practices.

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Chapter 15

Food Packaging Technologies in Post-Harvest

Shivangi Jain* and Ramandeep Singh
School of Business Studies, Punjab Agricultural University, Ludhiana
**Corresponding Author's Email : shivangi-2058007@pau.edu*

Abstract

Supporting agriculture in developing nations is the most effective way to enhance the lives of millions of people living in poverty. In agriculture, post-harvest handling activities are indeed, responsible for preserving food quality as it travels through the supply chain. Food packaging plays an important role in controlling post-harvest loss right from crop harvesting to its final consumption. In order to keep up with the highly competitive world, changing consumer preferences, technological advancements, environment and food safety concerns, packaging industry has grown and innovated. As a result, certain advancements in food packaging technology such as active packaging, intelligent packaging, smart packaging, nanotechnology etc. have emerged. Such advancements have revolutionised the food packaging industry from mere packaging to an experience today. However, environmental issues associated with packaging waste have grown dramatically in recent decades. Such issues call for a more sustainable approach towards food packaging material in order to set foot in the virtuous loop of circular bio-economy. This chapter discusses the advancements in food packaging technology, its challenges and future direction.

Key words : *Post-harvest, food packaging, intelligent packaging, nanotechnology.*

Introduction

Agriculture is the keystone for economic growth and development in any nation since it not only provides basic food to eat but also offers a diverse range of raw materials for industrial growth. As per the Food and Agriculture Organization of the United Nations, agricultural production needs to increase by 70 percent in order to sustain the world's population, which is expected to reach 9.1 billion by 2050 (Shinde, Rodov, Krishnakumar and Subramanian, 2018). With this ever-increasing population, the food industry is facing serious challenges such as growing food demand, emerging trend of sustainability, food and nutrition security, and increasing food loss and wastage. Among agriculture, post-harvest technology has the ability to fulfil the growing food requirements of people by eliminating food waste and ensuring food security throughout the supply chain. Postharvest technology is the handling of agricultural produce after harvest for its systematic conservation, processing, packaging, distribution, and marketing to meet the food and nutritional needs of the final consumer. The storage of harvest surplus has become very important to avoid post-harvest loss. Lowering postharvest losses would not only add a significant amount to the global food supply but also minimise the need to intensify food production while also reducing the harmful environmental effects of food production (Elik *et al.,* 2019). Among post-harvest technology, packaging is the most important aspect that extends the shelf life of products and promotes food quality and safety. Packaging is basically done for ease of storage and handling, efficient marketing, a wider appeal, and

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a longer potential life. Good packaging not only protects the food from physical, chemical, and biological contamination but also serves as a strong promotional tool.

Concept of food packaging

Food packaging is a blend of science, art, and technology that protects products from physical, chemical, microbial, and environmental hazards. Packaging is required to ensure the quality, safety, and authenticity of produce and processed products from the farm or factory to the end customer. Packaging can be defined in numerous ways, each highlighting a different aspect. Packaging, for example, can be viewed as :

> "a reliable way of ensuring safe, cost-effective delivery to the customer in ideal condition".
>
> "an effective, coordinated system of making commodities and produce fit for transportation, distribution, storage, retailing, and the final use for which they are intended".
>
> "a techno-commercial function that seeks to reduce delivery costs while increasing sales and, hence, profits".

Importance of food packaging in post-harvest

The post-harvest and marketing systems are a series of interconnected activities that begin after harvest and continue until the food product is delivered to consumers. Proper food packaging reduces food waste to a great extent by lowering the risk of damage caused by handling, transportation, environmental and biological deterioration in the storehouse, transport vehicles, retail stores, or open markets (Gardas, Raut and Narkhede, 2018). It ensures that food products are delivered in factory fresh condition at the lowest possible cost.

Post-harvest loss is a major obstacle to doubling the farmer's income and has plagued the whole supply chain industry. Different products need different types of packaging depending on their physical, physiological, and anatomical nature. Innovative and smart packaging technologies help to reduce post-harvest loss and keep the food fresh for a longer time. For example, Tetra Pak's aseptic technology is the greatest invention of all time that can keep food safe and fresh for months without refrigeration or preservatives. Packaging serves as a barrier against tampering or adulteration. Further, the food label on the packaging provides the customer with necessary information regarding the nutritional content and helps them make informed choices. At present, packaging has developed from a logistical role to protect and safeguard a product throughout its distribution in the supply chain to a marketing function that must be fulfilled before the product reaches its final consumer. In this context, food packaging design plays a critical role in persuading potential customers to buy a product and is the major reason for most impulse purchases around the globe. Thus, packaging acts as a silent salesman that promotes the product on the shelf.

Advancements in food packaging technology

The food packaging industry has advanced rapidly and significantly over the last few decades, but the most innovative advancements are yet to come. Changing business dynamics, consumption patterns, legislative frames, and distribution and retail trends are the major drivers of innovation in food packaging. Some major advancements in the field of food packaging are given below:

Active packaging : As opposed to traditional packaging, active packaging is a novel approach that aims at preserving or extending the shelf life of food products while assuring their safety, quality, and integrity. Active packaging can be defined as packaging systems that interact with food in such a manner that they "intentionally integrate some components that would release or absorb substances into or from the food products or the environment surrounding the food products." Active packaging is designed to react to changes in the environment both inside and outside the packaged food. Some commonly used active packaging systems are ethylene, carbon-dioxide, and oxygen scavenger; moisture and odour absorbers; modified atmosphere packaging; and antimicrobial and antioxidant packaging (Yildirim *et al.,* 2018).

Intelligent packaging : Intelligent packaging is concerned with the real-time monitoring of food quality all across the supply chain to control food-borne illnesses. Intelligent packaging materials are defined by the EFSA as "materials and articles that monitor the condition of packaged food products or the environment surrounding the food products." It differs from active packaging in the sense that it does not directly interact with the food product but, its goal is to monitor the food quality and transmit the information during transportation and storage. Three major technologies that are used in intelligent packaging systems are data carriers, indicators, and sensors (Muller and Schmid, 2019).

Data carriers aid in the efficient flow of information throughout the supply chain. The purpose of data carriers is not to monitor product quality but to ensure traceability, automation, theft protection, and counterfeit protection. Barcode labels and RFID (Radio Frequency Identification) tags are the most commonly used data carriers. Barcodes are inexpensive, simple to use, and widely used to help with inventory control, stock recording, and checkout. RFID tags are advanced data carriers that allow automated identification and data collection using sensors without any human intervention. It has the advantage of promoting quality, safety, traceability, and inventory management. ***Indicators*** identify the absence or presence of a substance, the magnitude of reaction among various substances, and the concentration of a specific substance. They are placed either inside or outside the packaging, depending on the type of indicator. The two most commonly used indicators are time temperature indicators (TTIs) and freshness indicators. TTIs are cheap, simple, user-friendly, and easily accessible devices, e.g., Fresh-Check from Lifeline Technologies. Freshness indicators monitor the quality of food products while they are in storage and transportation, e.g., SensorQ™ smart label. A ***sensor*** is a device that detects, locates, or quantifies energy or matter by producing a signal in order to detect or measure a physical or chemical property to which the device responds. Different sensors are used depending on the type of parameter under investigation, such as gas sensors and biosensors. Gas sensors can monitor the progress of spoilage by determining the concentration of specific gases like CO2, H2S, etc.

Smart packaging : Smart packaging offer a complete packaging solution as it monitors the changes taking place in a food product or its environment using sensors (intelligent) and takes action on these changes (active). Thus, it combines the benefits of both active and intelligent packaging. With the help of smart packaging technology, the whole supply chain, i.e., from manufacturer to retailer to end consumer, can easily gain information about the condition of a food product at any time. It helps preserve food and improves safety while reducing plastic waste. Researchers at Harvard T.H. Chan School of Public Health and Nanyang Technological University, Singapore, have developed a smart packaging material out of biodegradable corn protein known as zein. They conducted an experiment using this smart packaging material and figured out that the strawberries encased in this packaging remained fresh for 7 days, as compared to strawberries wrapped in a standard plastic fruit box that remained fresh for just 4 days. Since this protection is only provided when it is required, the taste and composition of the food in the packages are well preserved. But still more research into sustainable and biodegradable smart food packaging is needed so that manufacturers can start producing these materials on a large scale.

Nanotechnology : Nanotechnology has revolutionised many domains of food science with its numerous applications, especially in the field of agriculture and post-harvest processing, including packaging, storage, and transportation. Nanomaterial treatments have recently shown promising results, and they are being researched to minimise the use of synthetic fungicides to limit post-harvest rot in fruits and vegetables. Nanomaterials have gained a lot of attention in recent times because of their extraordinary properties, which make them ideal for food packaging applications because they improve the physical, mechanical, and thermal properties of packaging, such as gas barrier properties, temperature and humidity resistance, mechanical strength, and flexibility.

Nano-coating is the most widely used method for enhancing the properties of food packaging. It is a coating of food in the form of a thin layer or film that is placed or covered on food in order to make a mass transfer barrier. Such coatings can also be made from edible materials and directly applied to the product. Edible nano-coatings are used in the meat-processing industry, agriculture (to protect fruits and vegetables), cheese and bakery industries, and so on. Furthermore, Nanoclays are also used as nanomaterials for food packaging due to their mechanical and thermal barrier properties, which improve the physical characteristics of packaging and are low cost. Nanosensors can detect food-borne pathogens, adulterants, chemical contaminants, bacteria, fertilizers, pesticides, etc. Invisible Nanobarcodes can be used to verify product reliability and brand protection. Nanocomposites are the most promising of several nanomaterials for food packaging. It plays an important role in enhancing the barrier properties, strength, antimicrobial properties, and heat and cold stability of food packaging.

Innovations in food packaging technologies developed in response to consumers' growing desire for ready-to-cook or ready-to-eat, moderately processed food products with a longer shelf life and improved quality. Certain other advances in food packaging technologies include edible coatings and films and sustainable and biodegradable packaging.

Challenges in food packaging technology

Packaging is a vital component of modern food supply chains, and it plays an important role in protecting the quality of food products from environmental, chemical, and physical hazards. However, environmental issues associated with packaging waste have grown dramatically in recent decades. Some of the challenges that the packaging industry is experiencing today range from greenhouse gas emissions, plastic waste, and growing landfills to the depletion of limited resources and inadequate recyclability. Recycling helps reduce waste, save resources, and make a contribution to reducing climate impact, but this alone cannot eliminate the environmental impact of packaging. Only 13.5% of global waste is recycled, and 40% of plastic waste ends up in the environment, having a negative effect on us and our planet. Among possible alternatives, the production of microbial biodegradable polymers from agro-food waste residuals or by-products appears to be a viable route to developing an innovative, more resilient, and productive waste-based food packaging economy by detaching the food packaging industry from fossil feedstocks and allowing nutrients to return to the soil.

Future of food packaging technology

The food packaging industry is growing at a faster pace with rising consumption and urbanization. Because consumers are choosing healthier, on-the-go lifestyles, their demand for safe and convenient food packaging is increasing. But at the same time, they are not even willing to give up on sustainability. So now it is time to develop food packaging material that promotes a low-carbon, circular economy without jeopardising food safety. To meet changing demands, the industry is raising awareness about the significance of paper-based aseptic carton packaging. As per forecast, the global paper and paperboard packaging market will reach a value of more than 250 billion dollars by 2026 (Statista, 2022). This growth is coming in response to the growing demand for corrugated boxes from the e-commerce industry. Apart from this, the future of packaging will move towards sustainable materials made of agricultural crop waste, plant extracts, and bio-based and chitosan-based biodegradable films so that we can enter the virtuous loop of the circular bio-economy.

Conclusions

Food packaging technologies are constantly improving as a result of changing consumer lifestyles and the growing demand for high-quality, safe foods. Food packaging helps reduce post-harvest loss by extending the shelf life of food while also maintaining its sensory properties, quality, and safety. However, efforts should be made to limit the technical constraints and high costs involved in developing new packaging materials. Nowadays, researchers studying packaging strive to promote environmental sustainability. With the advancements in sustainable or eco-friendly food packaging, the impact of packaging on the environment can be significantly reduced via the use of biodegradable or edible materials, agricultural waste, plant extracts, bionanomaterials, etc. Apart from human health considerations, the carbon, energy, water, and land footprints must be considered when developing new food packaging materials.

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Chapter 16

Homegrdens : Sustainable Agroforestry System

Mahala Vrushali R.* and Akshay Pingale
Department of Forest Products, (Wood science and Technology)
Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan (H.P.)–173230
**Corresponding Authors Email : vrushalimahala0594@gmail.com*

Abstract

Home gardens are widely regarded as the model for sustainable agroforestry systems. The most intricate artificial combination of trees, crops, and animals provides essential ecosystem services while closely approximating a natural ecosystem. High biodiversity, helpful nutrient cycling, minimal reliance on outside resources, and the opportunity for soil conservation are also present. The home garden has great potential for in situ conservation of heritable income and economic worth of the produce grown. The economic benefits are the advantages beyond ensuring food and nutritional security and sustenance. The environmental benefits are the complexity of home gardens that can make them resemble ecological agricultural production systems that support biodiversity preservation. Function and structure are inextricably intertwined. Persistent pressure for change is brought on by demographic, economic, technical, and social factors. Home gardens are adapting to changing livelihoods. Maintenance of biodiversity and carbon sequestration is the complementary environmental service of any ecological unit, including agroforestry. The role of women in managing home gardens depends on several factors, including their careers. The secret to transforming home gardens into sustainable businesses is to make them productive and long-lasting. Home gardens are not an exception; changes in the local ecology, economics, and culture will undoubtedly have an impact on them.

Introduction

The term "agroforestry" refers to a method of sustainable land use that integrates livestock, tree crops, and/or arable crops into a single land management unit, either spatially or temporally. The most intricate man-made combinations of trees, crops, and animals provide important ecosystem services while closely approximating a natural ecosystem. Home gardens are widely regarded as the model for a sustainable agroforestry system. Home gardens are small, multistory arrangements of diverse annual and perennial crops that are either permanent or temporary and appropriate for tropical regions with heavy rainfall, sometimes in conjunction with domestic animals. A 0.20-to 0.50-hectare area is devoted to home gardening. High biodiversity, effective nutrient cycling, minimal reliance on outside resources, and the opportunity for soil conservation are also present. Standard resource management home gardens in agroforestry systems, for example, may offer options for improving livelihoods through concurrent food production (either directly through food grains, fruits, vegetables, and root crops, or indirectly by improving soil conditions and thereby promoting understory crop productivity, especially on degraded sites), fodder and firewood, high biodiversity, low use of external inputs,

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soil conservation potential, nutritional security, and ecological benefits).

Only the first two elements of certain home gardens' agri-silvicultural systems are present. As a result of farmers' ability to adapt to shifting rural and livelihood situations throughout generations, home gardens, however, are not static but rather have changed. Due to the lack of boundaries between them, it is difficult to distinguish where home gardens end and other farmed areas start. The families who maintain them receive a varied and consistent supply of socioeconomic goods and advantages. From the perspective of system dynamics, the concept of sustainability has two fundamental components: social sustainability and ecological sustainability (in the sense of remaining within ecological stability areas).

Benefits of Homegarden

The home garden has great potential for in situ conservation of heritable income and economic worth of the produce grown, which can either be sold for what it is or what the owner would pay to buy it (Vasey,1990). Consuming vegetables from a home garden can lower the percentage of household income going toward food. Home gardens can offer other services like furnishing, medication, and decoration. The economic gain from selling home garden foods and products varies greatly depending on the size of the garden, the needs of the household, and plant diversity (Kumar and Nair, 2004). The variety of plants in the garden directly relates to the amount of money saved or generated by home gardens. For instance, savings are more when a home garden produces a complete diet because fewer food products need to be purchased. While simultaneously boosting local economies, this decreased reliance on imports improves food security and acts as a buffer against the financial instability of rising food prices globally. The home gardens include all of the benefits of keeping an area forested or planted; these benefits include sequestration of carbon by plants, soil building, protection against land erosion, and decreased water runoff (Elevitch and Wilkinson, 2000).

Economic Benefit : In particular, for households with limited resources, home gardens have economic advantages beyond ensuring food and nutritional security, and sustenance. Many nations actively support home gardens as means of preventing poverty and as a source of income for people living on a subsistence level in developing countries. Home gardens are organized to be more effective commercial operations by producing high-value crops and practicing animal husbandry, although they have typically thought of as subsistence-low productivity systems. For families with limited resources and access to production inputs, the fact that home production is less expensive and requires fewer inputs and investments is crucial.

Environmental Benefit : The majorities of home gardens are diversified and feature a wide variety of plant and animal species. Multiple environmental and ecological advantages come from home gardens. They act as the organization that develops and implements environmentally sustainable methods of food manufacture while preserving biodiversity and other natural resources. The complexity of gardens can make them resemble ecological agricultural production systems that support biodiversity preservation. A home garden's outstanding traits include its rich species diversity and composition and its dense dispersion of faunal and floral layers. A variety of ecosystem services are also offered by home gardens, including improved pollination, reduced soil erosion, habitats for animals and other beneficial species, and nutrient recycling. The home garden's dense plant population offers the perfect habitat and haven for wildlife species like birds, small mammals, reptiles, and insects. A very effective nutrient cycling system is made possible by the availability of plant and animal waste with the ongoing recycling of organic soil material. Reducing soil erosion and preserving land are two additional advantages of home gardening.

Social Benefit : Strengthening food and nutritional security in socioeconomic and political contexts, enhancing family health and human potential, empowering women, supporting social justice and equity, and maintaining indigenous knowledge and culture are just a few of the social advantages of home gardens. Home gardens directly contribute to household food security by increasing the availability, accessibility, and consumption of food products, which is the most fundamental social benefit they may provide. Plants are a significant source of medication for people and animals, and they are also utilized as biological insecticides to guard crops against pest infestations and illness. Nearly 80% of people in developing nations use herbs and medicinal plants, which are grown in home gardens around the world, to treat a variety of illnesses and diseases as well as to improve their general health.

Design and Elements of Home gardens

The abundance of species in the home garden, which ranges from crawling plants like the sweet potato to tall trees that may reach heights of more than a meter, like a coconut palm, and vines that cling to bamboo poles and trees, is a striking structural feature. Function and structure are inextricably intertwined. There are typically no rows, blocks, or distinct planting distances between components, which results in a forest-like form.

Plants	Economic Use
Lemon grass (*Cymbopogon citratus*)	Spice
Hibiscus Spp.	Ornamental
Ginger (*Zingiber officinarum*)	Medicinal, Spice, Cash crop
Jackfruit (*Artocarpus hetrophylla*)	Fruit, Timber, Fuelwood
Banana (Musa spp.)	Fruit, Cash crop, Subsidiary staple food
Mango (*Mangifera indica*)	Fruit, fuelwood, Cash crop
Muntingia calabura	Fuelwood, Shade
Turmeric (*Curcuma longa*)	Spice, Medicinal, Cash crop
Sweet potato (*Ipomoea batatas*)	Subsidiary staple food, animal feed
Sandoricum koetjape	Medicinal, Fruit, Constructional material

A residential garden appears disorganized to a passing onlooker. A common misconception is that the structure's resemblance to a forest is the result of planning. This is dubious because trees do not hold significant cultural significance in Java, where such household gardens are quite well established. Therefore, it seems impossible that anyone would purposefully plant a "forest" near their home. Changes in vegetation structure and composition may not always be detrimental to the production processes if the nutrient cycle mechanisms, hydrological conditions, and synergistic interactions are not compromised. As a result of the persistent pressure for change brought on by demographic, economic, technical, and social factors, home gardens are adapting to changing livelihoods (Kumar and Anjali, 2017).

Characteristics of Home gardens

The main features of a typical home garden

List the following five inherent qualities of home gardens: 1) are close to the home; 2) have a wide variety of plants; 3) production is supplemental rather than the primary source of family consumption and revenue; 4) take up little space; and 5) are an accessible production system for the underprivileged (Michelle and Hanstad, 2014). Ecologically, there are two types of home gardens: tropical and temperate. Home gardens are frequently built on marginal or unsuitable sites due to their size, topography, or location for growing field crops or grazing. Physical barriers, such as living fences or hedges, ditches, or borders agreed upon by both parties, may be used to separate the house gardens. Family members are frequently employed to work in the home garden; women, kids, and elders are especially important in their administration. However, depending on their financial means and affordability, households might hire wage laborers to cultivate and maintain their home gardens, which would after that changes the nature and volume of related activities.

The main features of a typical home garden

Characteristics	Standard procedure
Ratio of species	High
Type of species	Staples, vegetables, fruits, medicinal plants
a production goal	consumption at home
labour provider	Family (Women, elderly, children)
requirements for labour	Part time
Harvesting cycles	Daily, seasonal
use of space	Horizontal and vertical
Location	Near dwelling
Cropping style	Irregular and row
Technology	Simple hand tools
Input-cost	Low
Distribution	Rural and urban areas
Skills	Gardening and horticultural skill
Assistance	None, minor

Carbon sequestration potential of homegarden

Home gardens, one of the agroforestry systems, have the potential to reduce greenhouse gas (CO2) accumulation in the atmosphere while easing the strain on the natural forest cover throughout the carbon sequestration and storage process. Consequently, they could view as a promising strategy for reducing climatic changes. Maintenance of biodiversity and carbon sequestration is known as the major complementary environmental services of any ecosystem, including agroforestry (Kumar, 2006). In favor of these findings, homegardens are now being considered as climate-smart, tree-crop integrated, subsistence-level farming systems, which are resilient to extreme climatic hazards (Gifawesen *et al*., 2020). Tree-based agroforestry increases atmospheric C sequestration process, which ultimately reduces the atmospheric CO_2 and assists in moderating climate change implications (Wilson and Lovell, 2016).

Women's role in home gardens

Women are crucial in the introduction of many crops, especially near home gardens. The role of women in managing home gardens varies on several variables, including their career, the size of the gardens, the availability of jobs off the farm, and the family's socioeconomic situation. The finest example of where women work more on homestead farms than men is in the home gardens. Women took a very active role in a variety of tasks, including agriculture (90%), horticulture (85%), managing livestock (90%), and home chores (85%). It is estimated that household work made up around 94% of all the days that women worked. (Dunkelman and Davidson, 1988). (Sankar and Chandrashekara, 2002) recorded that in about 60% of the total number of small home gardens (0.4 ha), women contribute significantly to the management of the system. They also reported that the role of women in garden management is significant in only 22% and 12% of the total number of medium-sized homes (0.41-0.012ha) and large homes (>1.2ha). The possibility of gender equality in home garden management and benefit sharing is one of the major stimuli for home gardeners' continued household food security (Kumar & Nair, 2004).

Significance of ecosystem services

The benefits that natural ecosystems provide for human well-being are referred to as ecosystem services. Ecosystem services range from material benefits like wood production, carbon sequestration, improved soil fertility, wildlife protection, supply of clean water, pest and disease control, biodiversity preservation, upkeep of hunting and tourism-related recreation areas, and agricultural products to immaterial advantages like climate regulation and aesthetic features. The importance of managed ecosystems in the provision and upkeep of essential services in promoting social-ecological resilience has been highlighted by the economics of ecosystems and biodiversity. Through a nutrient pumping mechanism, the close relationship between the annual and perennial components improves nutrient recycling and decreases sensitivity to soil erosion. People can benefit from the natural environment in many different ways. The multi-strata home garden in an agroforestry system provides a wide range of services for human needs, including food, medicine, firewood, building materials, fiber, animal feed, shade, and ornamental and spiritual purposes. The home garden system offers essential ecological services as, regulatory, cultural, and auxiliary services.

Major Issues for Sustainable Production System

The sustainable management of agricultural resources to meet shifting human requirements while preserving or improving the environment's quality and natural resource conservation. The creation of species-specific pruning and thinning regimes, protection against the main pests and diseases, and the accessibility of high-quality planting materials and their straightforward propagation based on cost-benefit analysis, the ideal rotation period; examine the current wood market structure and agroforestry businesses to encourage the essential trade and industry connections for employment and income production for rural people, especially for women.

Opportunities and Challenges of Homegardens

Due to a lack of quantitative data on the type, scope, and cultural and ecological relevance of house gardens, the majority of planners and policymakers in the tropics do not fully comprehend the implications of home gardens for planning. In the urban setting, home gardens constitute a crucial part of a sustainable agroforestry system. The secret to transforming home gardens into sustainable businesses is to make them productive and long-lasting. The lack of ownership and other types of usage rights, as well as the lack of suitable and sufficient land to build a home garden, were found to be the key limiting factors. It covers having access to markets, water, labor, seeds, and other agricultural resources. Home gardens are not an exception; changes in the local ecology, economics, and culture will undoubtedly have an impact on them. Concerns about the future of home gardens, especially the potential for bringing technological innovations to the practice of home gardening, are naturally raised by the youth migration to urban and even foreign centers in search of jobs and cash income, a common feature of societies dominated by home gardens.

Conclusions

Home gardens are widely regarded as the model for sustainable agroforestry systems. The most intricate artificial combination of trees, crops, and animals provides essential ecosystem services while closely approximating a natural ecosystem. Home gardens can offer other services like furnishing, medication, and decoration. The economic gain from selling home garden foods and products varies greatly depending on the size of the garden, the needs of the household, and plant diversity. There are typically no rows, blocks, or distinct planting distances between components, which results in a forest-like form. The potential to reduce greenhouse gas (CO_2) accumulation in the atmosphere while easing the strain on the natural forest cover throughout the carbon sequestration and storage process. Women took a very active role in a variety of tasks, including agriculture (90%), horticulture (85%), managing livestock (90%), and home chores (85%). It is estimated that household work made up around 94% of all the days that women worked. The multi-strata home garden in an agroforestry system provides a wide range of services for human needs, including food, medicine, firewood, building materials, fiber, animal feed, shade, and ornamental and spiritual purposes.

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Chapter 17

Project Formulation and Execution Related to Precision Farming

A. Qureshi[1*], C.R. Netam[2] and O.P. Parganiha[1]
[1]*College of Agriculture and Research Station, Marra (Patan) Chhattisgarh*
[2]*College of Agriculture and Research Station, Gariyaband, Chhattisgarh*
**Corresponding Authour Email : qureshi.ameen76@gmail.com*

According to Robert *et al.,* (1995) Precision agriculture is defined as information and technology based agricultural management system to identify, analyse and manage site-soil, spatial and temporal variability within fields for optimum profitability, sustainability and protection of the environment. Successful implementation of precision farming depends on numerous factors, including the extent to which conditions within a field are known and manage, the adequacy of input recommendation and the degree of application control.

Components of precision agriculture

Basically precision agriculture relies on the interaction of three broad and fundamental components. They are categorized in terms of information, technology and management (Pierce and Peter, 1999).

Information : In field soil and crop varies both spatially and temporally. The information related to soil properties, crop characteristics, weed and insect population and harvest data are important database that need to be developed to realize the potential of precision agriculture. Of these, entire crop yield monitoring is the most important component of precision agriculture technology and is the logical starting point for precision agriculture. It gives the farmer something to look at and start raising questions about his practices. Establishment of soil related characteristics within a field through regular soil sampling is another important database. Precision agriculture therefore has to be made on what property to sample, how to sample and how often to sample so that interpretation from database can be made with greater confidence.

Technology : The recent developments in IT and space technologies for monitoring yields and sensing soil related variables are new tools available to make precision agriculture a success. When measuring field characteristics such as moisture, nutrient and crop data, satellite based positioning system like Global Positioning System (GPS) can be used to identify the location where the data are taken. Organisation of these data into usable form such as different layers of field maps, can be achieved through personal computer (PC) and Geographic Information System (GIS). Remote sensing techniques can also be utilized to detect soil related variables, pest incidence and water stress (Dalal and Henry, 1986; Shank *et al.,* 1991: Leone *et al.,* 1995). The basic idea of Precision agriculture is not only to measure the field variability, but also able to apply inputs at varying rates almost instantaneously in real time according to the needs. Variable rate application (VRA) machinery is a type of field implements that could be used to handle field application of inputs such as seed, fertilizers and pesticides at the desired location in the field at the right amount, at the right time and for the right reasons.

Management : Precision agriculture makes planning both easier and more complex. The ability to combine the information generated and the existing

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technology into a comprehensive and operational system is the third key area in Precision agriculture. A farmer must adopt a new level of management proficiency on the farm. Implicit in this is an increased level of the knowledge of the Precision agriculture technologies such as GPS and GIS, better understanding of soil types, micro climates, aerial photography and economics of agriculture for accurate assessment of risk based on different decisions.

Tools of Precision Agriculture

The tools of precision agriculture are much like pieces of a puzzle which are interconnected to form a complete system. These can be a powerful management tool which can be increase net returns by using resources more effectively, which are discussed below :

GPS or the Global Positioning System, is a constellation of 24 satellites operated by the US Department of Defence which transmit precise time and orbit information. A receiver on the earth can determine its location to within 100 m using signals from these satellites and be as accurate as 1 cm using differential GPS. GPS is used for topographic surveying or in conjunction with other sensors to provide geo-referenced (x, y coordinate) maps of yield, salinity, or anything else which can be measured and you would want to map.

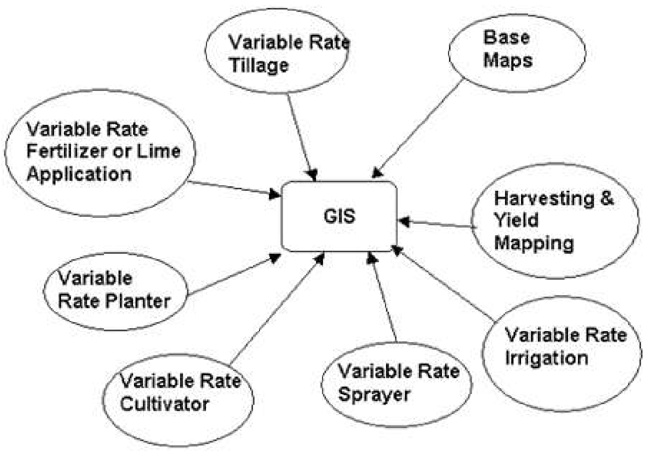

Fig. : Precision farming overview.

GIS or Geographic Information System, are used for handling large amounts of geo-referenced data. Maps can be viewed in layers to see the relationships between them. A GIS is basically a database of information which has x and y coordinates attached to that data.

Yield Monitors allow instantaneous yield data to be collected from very small areas of the field to see the variation of yield. They may also collect moisture and possibly protein data as well. There are yield monitors available for most grain and bulk crop harvesters.

Variable Rate Application of fertilizer, seed, and pesticides can be done using controllers to vary the rate on the go. This can be computer controlled according to a prescription map or varied annually.

Crop Scouting and Remote Sensing is important to note problems in the crop and make records of sloughs, field boundaries, rocks, etc.

Information transmission Type and amount of information collected and transmitted among different mobile and static electronic equipments used in agriculture are increasing rapidly which create requirement for standardized format for electronic communication.

Delineation of Management Zones

One approach to apply precision agriculture to optimize crop production and environmental quality is identifying management zones. Management zones (MZ) are defined as sub-regions of a field that has a relatively homogeneous combination of yield-limiting factors, for which a single rate of a specific crop input is appropriate to attain maximum efficiency of farm inputs. Besides representing areas of equal production potential, within-field management zones have many other uses. Several studies have indicated that homogenous management zones could be used as an alternative to grid soil sampling and to develop nutrient maps for variable rate fertilizer application. Spatially coherent areas within fields may also be useful in relating yield to soil and topographic parameters for crop-modelling evaluation .

While methods for delineating management zones vary widely in the information used, usually they are based on soil and yield information possibly over several years. Many researchers used the soil and/or relief information viz., soil EC, fertility , texture, topography etc., to define management zones. But EC based management zones were found more reliable.

The second approach is based on yield maps, combining data from several seasons. Yield maps are being used to identify generalized management zones of low, medium and high yield productivities. Some have used a series of yield maps to classify the management zones with different relative yield and yield stability within a field. Other published researches delineated filed zones into different yield potential as a function of soil and topography characteristics caused by erosion.

The third approach integrates the soil information with yield data to delineate subfield management zones. Some scientists utilized a variety of data resources such as topography, soil EC, crop yield maps and intensive soil survey data to construct management zones for N fertilizer management. In addition, current information on crop status, for example by remote and surface sensing, can be considered as a valuable tool which enables the management zones to be adjusted to the current growing season while many have concluded that aerial photographs of growing crops were the most accurate for classifying a field into management units to predict grain yield.

The combination of the different layers of information can be performed using different algorithms. The most common is the use of cluster analysis. This can be used to identify areas that have similar landscape attributes, soil properties and plant parameters, to quantify patterns of variability and to reduce the empirical nature of defined management zones. Fuzzy clustering of combined yield monitor data to divide a field into potential management zones is considered as a powerful tool. Many have found approximately 54% of the yield variation was explained by the identified management zones using cluster analysis of apparent EC, elevation, and slope information.

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Chapter 18

Technological Innovations in Nursery Management

Vedika Sharma*, Amit Saurabh, Sujan, Anjali Thakur and Abha Sharma
Department of Horticulture, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib
**Corresponding Author Email : vedikasharmahimansh@gmail.com*

Abstract

Agriculture is the backbone of our country and has a prime role in Indian economy. Under Agricultural sector Horticultural crops play very important role to economy. The area under horticulture grew by 27.56 million ha and production increased by 333.25million tone (Department of Agriculture and Farmers Welfare 2021-2022). In the country production of vegetable has increased for 58.53 million to 199.9 MT since 1991-1992 to 2021-2022 (Department of Agriculture and Farmers Welfare 2021-2022). A good seed sown in a good field, results in a very good yield, raising healthy seedlings under good nursery management practices is an important part of successful vegetable production (Yadav et al. 2017). Crop grown by nursery raising is quite early and fetch higher price in the market so economically more profitable, there is saving of land and labor as main fields will be occupied by the crop after one month, it allows more intensive crop rotation. More time is available for preparation of main field as nursery is grown separately, vegetable seeds are very expensive particularly hybrids, so we can economized the seed by sowing them in the nursery. We use various types of growing media other then soil for raising our nurseries as they have good water holding capacity, porosity and many other properties like, it provide support to the plant (Waiba et al. 2020).Good and suitable nursery potting media influence good and quality seed production (Alabi *et al.* 2019).

There are two types of nurseries i.e. temporary nursery (for a season) and permanent nursery (placed permanently for continuous production). Different seed treatment should have been practiced so seed gets good insurance against disease, soil borne organisms and thus affords protection to weak seeds enabling them to germinate and produce seedlings. Also use the manure to nursery land that can help maintain and improve soil organic matter levels and improve soil tilth, soil structure, water infiltration, nutrients and water holding capacity and reduce soil erosion. Nursery can be raised in different containers like polybags, protray, disposal cups, hydroponics etc. and nursery can also be raised in protected conditions as seedlings grow early and fetch higher price in the market so economically more profitable also the saving of land and labour as main field will be occupied by the crop for lesser duration. We can use different structures like greenhouse, net house, soil trench, poly tunnels etc.

Key words : *Hydroponics, management, production, seed, structures.*

Introduction

Nursery management system collects important data and useful data, access information, target markets, increases staff productivity and improves customer's satisfaction (Kapole *et al.* 2020). The aim of good nursery management is to make available

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planting material of the highest possible quality for new development areas and replanting (Bhandari *et al.* 2020). Raising nursery from seed provides an easy and convenient way to nourish tender young seedlings in a well-managed small and compact area. Some of the vegetable seeds are very costly, for which it is necessary to raise nursery in the most optimum conditions. In areas where land holdings are small, nursery raising helps in making economical use of land for about one month and provides enough time to mature for previous crop, harvesting, threshing and land preparation for next crop.

Nursery

A nursery is a managed site, designed to produce seedlings grown under favourable conditions until they are ready for planting. All nurseries primarily aim to produce sufficient quantities of high quality seedlings to satisfy the needs of users.

Objective of Nursery

It occupies an important place in artificial regeneration. The following objectives for which nursery is generally made, clearly bring out its importance.

Some important species do not seed ever year. Plantations of these species can be raised annually, only by sowing all available seeds in nursery to raise seedlings to be planted out various years.

Some species grow very slowly and if the seeds of these species are sown directly in plantation, the seedlings are most likely to be suppressed by weeds and ultimately killed. Therefore, slow growing species are generally raised in nursery and planted out, only when the seedlings are not liable to be damaged by weeds.

Plantations of some species, when raised by direct sowing are not so successful when raised by transplanting their seedlings. In such cases, nursery is an essential part of artificial regeneration to these species.

Importance of Nursery and its Role

Seedlings and grafts are produced in nursery from which the fruit orchards and ornamental gardens can be established with minimum care, cost and maintenance.

It is possible to grow and maintain a large number of plants per unit area.

The nursery planting materials are available at the beginning of the planting season. This saves the time, money and efforts of the farmers to raise seedlings.

It assures the production of genetically improved quality planting material.

It provides employment opportunities for technical, skilled, semi-skilled, unskilled labor.

Advantages of Nursery Management

Crop grown by nursery raising is quite early and fetch higher price in the market, so economically more profitable.

There is saving of land and labor as main fields will be occupied by the crops after 1 month. More intensive crop rotations can be followed.

More time is available for the preparation of main field because nursery is grown separately.

Germination percentage of seeds is normally high.

Operations like weeds and plant protections are easy.

Selection of the Nursery Site

Location : A nursery should be located in a pollution free environment. Nursery beds are generally made near the well or the irrigation source for easy and timely availability of water. It should be located in sunny area.

Soil type : The soil must preferably be loam and sandy loam with large quantity of organic matter. The ph of the soil must be neutral (6.5-7.5). It must have adequate water retention capacity and aeration.

Water : The nursery must be located near a water source. The quality of water used in a nursery is important for the growth of plants. Saline and polluted water must not be used.

Drainage : The nursery site must have adequate drainage facility and be free from waterlogging. Water must not stagnate at any time.

Labor : As nursery work is labor-intensive, the nursery site must have enough number of laborers.

Protection from animals : The nursery area must be protected by enclosures so as to prevent damage to the plants by stray animals. Fencing facility should be there to protect from wild animals.

Market : Market plays an important role in the success of nursery business. Various ypes of inputs like seeds, fertilizers, pesticides, fungicides, plant growth regulators, poly bags, agricultural implements, different type of spare parts and other miscellaneous items required in the nursery must be available in the nearby market. The nursery must be located near the city or an area from where people can purchase the plants.

Soil Management

To make the soil free from soil borne diseases like, damping off, bottom rot, Rhizoctonia disease, various methods like soil sterilization soil solarisation, chemical method and indigenous method are adopted especially in permanent nursery beds. However, in temporary nursery beds, soil sterilization can be avoided by shifting them to new sites.

Soil sterilisation : Sterilization of soil is the act of killing and destroying the act of disease causing organism that is present in the soil. Two methods of sterilizing the soil:

Steaming : Heating of the soil to 180°F and steaming at this temperature for 30 minutes.

Chemical : The use of chemical sprays, fumigants and dry formulations of pesticides to kill off harmful organisms that might be in the soil.

Solarization : Seed beds are prepared 6-8 weeks before seed sowing. These beds are drenched with water and are completely covered with transparent polythene sheets of 200-300 gauge, the sides of which are sealed with soil. This helps in the generation of high temperature that eliminates most of the soil borne infections.The polythene sheets are removed after 3-4 days and is most effective, when the day temperature is 35°C or more and the weather is dry.

Chemical method : The seeds beds are drenched with commercial grade formaldehyde (40 %) at the rate of 250 ml in 10 litres of water. After formaldehyde application the nursery bed should be covered with polythene sheets or gunny bags or tarpaulin for few days (48 or 72 hours) so that fumes may penetrate the soil and kill the harmful fungi and insects.

Indigenous method : In this method crop residue available near the nursery area are collected and burnt on the prepared soil, this will help in the destruction/ death of harmful fungi and insects. In case, the soil for the seed bed could not be sterilized, the beds may be treated with fungicides like captan (2g/litre of water), Bavistin (1g/litre of water). The beds can be treated with insecticides like furadan (3g/ litre of water), Bavistin (1g/ litre of water), Thimlet (10g/ litre of water) particularly in the areas where nematode incidence is a problem.

Bed Preparation

Temporary nursery : This type of nursery is developed only to fulfill seasonal requirements or a targeted project. Such a nursery is, usually, small in size and is set up for a short period. It is decentralized in nature and every year and can be shifted to other places. This type of nursery is economically cheaper and easily manageable.

Permanent nursery : In this type of a nursery, the plants are nourished and kept for a longer period of time till they are sold out or planted permanently in a field.

They must have regular layout, roads, sowing beds, irrigation source, drainage facilities, storerooms, labour huts, etc. These types of nursery are costly.

Based on Height from the Ground Level, the Nurseries can be

Flat bed : These nursery beds are generally prepared at ground level and recommended for raising seedlings in spring-summer season when there is no risk of rain and in the areas where the soil is light sandy to sandy loam and has no problem of water stagnation.

Raised bed : The raised nursery beds are prepared 15-20 cm above the ground level and provided with 30 cm wide drainage channel around them. The bed should not be more than 100 cm wide and it's length may be as much as desired. A space is 3-4 cm is left between two beds in order to carry out cultural practices smoothly

Sunken bed : Sunken beds are prepared by digging the soil 20-25cm deep. The seedlings can be protected easily from adverse environmental conditions by covering them with polyethylene sheet or leave thatches

Manuring

Since a nursery bed has to support a thick plant population for a month or more. It should be rich in nutrients. For a seed bed area of 3 m^2 two baskets of well rotten FYM should be applied and thoroughly mixed in the soil. A fertilizer dose of 35-40 gram of urea, DAP, and MOP should be added at the time of nursery bed preparation, however, quantity of chemical fertilizer depends upon soil status. If the growth of seedling is not satisfactory, spraying of urea (1-2%) may be done.

Seed Treatment

For controlling fungal diseases, the seed before sowing is treated with fungicides like Agroson GN, Thiram, Captan, Bavistin 2.5-3.0 g/kg of seed. Soaking of seeds in 0.02% solution of Streptocycline for 30-60 minutes is quite effective in controlling bacterial inoculum..

Methods of Seed Treatment

Dust Treatment : The seeds are treated by dust formulations in a closed barrel type rotating drums, which treat the seeds uniformly and quickly, reducing inhalation hazards.

Wet Treatment : The water-soluble chemicals are dissolved in the containers of convenient size, and seeds are dipped in the solution for a certain period. They are then dried properly before sowing or storage. It is time consuming and unmanageable method of seed treatment.

Slurry Treatment : Slurry is most suitable for applying wettable powder formulations.

Seed Pelleting : It is used mostly as protectants against soil organism and as repellent against birds and rodents. It ensures uniform coating of seeds with fungicides or bioagents. These seeds are shade dried and used for sowing.

Sowing of Seeds in the Nursery

After the seed bed is set, the seed is sown in various forms in the nursery bed. Those techniques are as follows.

Methods of broadcast : In the prepared nursery bed, seeds are transmitted and later coated with well rotten fine sieved and handled FYM or compost on the seeds. The major disadvantage of this method is there is uneven distribution of seeds in the nursery becomes dense.

Line sowing : Line sowing is the best nursery sowing form. Lines are rendered at a distance of 5 cm from the line 1 cm wide, parallel to the width. Seeds are planted or placed separately at a distance of approximately 1 cm apart..

Care After Sowing

Mulching : After sowing of seeds, about 5 cm layer of mulch is applied over the bed. Mulching helps in maintaining surface moisture essential for germination of seeds, prevents damage by birds, minimizes splash damage by water, avoids flow of seeds, suppresses weed growth effectively and minimizes the incidence of virus diseases by repelling the insect attack. Organic mulch may be dry leaves, straw, saw dust, paddy husk etc. Polyethylene mulch preferably black, is the commonly used synthetic plastic mulch. When seeds germinate, the layer of mulch is removed.

Thinning **:** The practise of removal of excess seedlings to facilitate aeration and better development is termed as thinning. The seeds of majority of the vegetables being small are difficult to sow uniformly, results in over-crowding of seedlings. Hence, removal of excess seedlings from the nursery becomes essential.

Hardening off : The seedlings raised under protected conditions of temperature and light and are maintained under shade with ample moisture in the soil, make them very tender and succulent. Such Plants when shifted in the field under open conditions receive severe set back and show mortality. To avoid this, the plants are subjected to hardening–off treatments.

Irrigation **:** Nursery bed should be irrigated with a rose can early in the morning for a few days till seeds germination without washing out away of soil. Seedlings should never be irrigated during mid day sunshineNumber of watering should be adjusted on the basis of day temperature sunshine, rain and soil type.

Types of Nursery Raising

Earthen pots nursery : The seedlings can be raised in earthen pots. The pot mixture combination which have coco-peat, neemcake and trichorich as its principal ingredients is considered good. This mixture combination provides the better germination of seeds during the process of seedling production.

Wooden/plastic box nursery : Seeds are sown in wooden/plastic boxes of 45 X 35 X 7.5 cm Size with 6-8 properly spaced holes in the bottom and one in centre. Against each of the hole a cork is placed with its concave side down. Seeds are sown 1 cm deep and 2 cm apart.

Polythene bags nursery : For most of the cucurbits seed propagation and in situ sowing is practiced. Seedlings are also grown first in poly bags as described below. This practice is generally used for raising early nurseries of cucurbits.

Plug tray (pro trays) nursery : Low cost protected structure using shade nets have started vegetable seedling production in protrays by using sterilized coco-peat as growing media. Shade nets would prevent virus causing pests to enter in the structure, the protrays reduce the root damages in seedlings and decrease excess water retention at base.

Disposal cups nursery : Paper and plastic cups should be used. Poke holes in cups from bottom, so that they will break down more easily once they are planted.

Hydroponics and aeroponics nursey : Hydroponics is the cultivation of crops in water-based methods. Hydroponics, is one which is gaining popularity among the farmers now a days. (Biswas et al. 2022). While aeroponics is the cultivation of plants by providing water and nutrients in the form of a mist.

Growing media : Growing Medium and its types It is a medium other than soil which is inert and non-organic material. It provides support for the plants to hold up them. There are different types of growing medium and they are as follows (Waiba et al. (2020)

Coco coir : This medium has excellent moisture holding ability and inert characteristics. It is made from a brown husk of coconut shell. It is sold in small compressed packets.

Perlite : It is inert material having light weight inexpensive growing media. It is made by heating it expands like popcorn. It is porous and has good water retention properties

Vermiculite : It is natural mineral having lightweight which is used as growing media in soilless cultivation. It is rot resistant growing medium.

Peat Moss : Peat moss is made from sphagnum moss that is decomposed in peat bogs over thousands of years. It is dark brown fibrous product of and other organic materials. It can holds moisture several times its weight in and releases slowly to the plants roots as required amount.

Sawdust : It is made from wood, produced by sawing. It is 100% natural, eco – friendly and easily available soilless growing medium.

Rockwool : It is inorganic material soilless growing media which is made into matted fiber. It is used especially for insulation and sound proofing. It can withstand extremely high temperatures since; it is fire resistant as well as noise resistant.

Coarse sand : It is a sand particle having a diameter of 0.5- 1 mm. It is used in soilless mixes. It doesn't retain water however; it improves drainage and aeration.

Pea gravel : It is a small piece of stone having size of the size of a pea about 1*8 inch – 3*8 inch. It imp

Greenhouse Nursery

A greenhouse nursery is a framed or inflated structure covered with transparent or translucent material (usually U.V. stabilized) large enough to allow a person to walk and where seedlings crops may be grown under partial or fully controlled environmental conditions to get optimum growth and productivity.

Advantages of greenhouse nursery

Seedlings can be raised under adverse climatic conditions where it is not possible under open field conditions.

It is suitable for raising the nursery of sexually and asexually propagated vegetables and ornamental crops.

Management of insect/pests and diseases under greenhouse conditions is quite easy particularly the infection of virus.

It reduces the seed rate in hybrid vegetables, looking to the very high cost of hybrid seeds in vegetables.

Polyhouse

A polyhouse is a framed or inflated structure covered with a transparent or translucent material (ultraviolet stabilized polythene film) in which seedlings are raised under partially controlled environment and which is large enough to permit a person to work in the poly house.

Net House

It is a framed structure consisting of GI pipes covered with ultra violet (UV) stabilized net of 40-mesh size. It is large enough to grow crops under partially controlled environmental conditions to get maximum productivity and quality produce (Narayan *et al*., 2009).

Hot Beds

A hot bed is one where heat is generated by decomposition of fresh manure. The heat generated is utilized for seed germination, which results in early nursery raising.

Nursery Cloches/Low Tunnels

Used for raising vegetable seedlings under unfavorable weather conditions. These cloches or tunnels are made curved and are covered with polythene. The end of these cloches/ tunnels can be closed with polythene sheets as per climatic requirement. Cloches prevent both hardening and frozening of land, thereby helps in sowing of seed earlier and when desired.

Thatches

Thatches are traditional structures used to protect the vegetable nurseries from unfavorable conditions both during winter and summer seasons.In winter thatches are erected in a slanting manner at 45 ° angle from ground level and are oriented in southwest directions.

Soil trench : During extreme winters, a trench of 150 cm width and 90 cm depth of varying length is dug and covered at top with polyethylene film to conserve solar heat.These underground green houses are very popular in Ladakh for raising seedlings to get early crop.

Precautions to be taken during the preparation of nursery

A nursery bed needs to be prepared carefully so that uniform and healthy seedlings are obtained for planting.

The nursery bed is, generally, used to germinate sown seeds or for rooting of cuttings planted in the soil.

The nursery bed must be prepared in fertile soil rich in organic matter content, having adequate drainage and aeration. Soil having more water retention capacity does not need frequent irrigation.

Excess irrigation in sunken or flatbed may lead to rotting of seeds, seedlings and damping-off incidence. Watering of the bed depends on the type of soil. Sandy soil needs frequent watering.

Nursery Pests and their Management

White Grub : Application of 200 g phorate or 50 ml of chloropyriphos mixed in 50 ml water may be used to spray for one bed.

Cutworms : Dusting of seed bed with a mixture of quicklime and ash or 1.5% quinalphos will control the insect.

Termite : The termite attack can be controlled by keeping the nursery cleared of wood debris, using well decomposed FYM and application of termiticides such as chlorpyriphos.

Crickets : Deep ploughing during nursery site preparation, application of 200 g phorate or fenitrothinon 5% dust per bed can control the pest.

Examples of successful model nurseries

Pragathi biotech Ltd., Jalandhar and Barathi grow more biotech Ltd., Bangalore are some examples of successful private owned nurseries feeding the demand of Eucalyptus saplings in north India and Banana, Bamboo, rose, other tissue culture plants in South India.

Profit functioning ITC, WIMCO, TNPL, JK, Star and Seeshasayee corporate nurseries used to meet the pulp and paper seedling requirements. The field nurseries established by them in villages under contract farming ensure the continuous supply of raw material.

The Kisan nurseries established in watershed areas eg. Puja nursery and Bhati nursery in village Bujawar, Jodhpur are some successful nurseries established to ensure livelihood and socioeconomic improvement of the people.

Conclusions

The productivity of vegetable in our country is very low as compared to advanced country. Poor nursery management is one of the potential factors responsible for this low productivity; thus, befitting nursery management for raising seedlings is an important operation in vegetable production. The success or failure of crop depends on health of the seedlings used for transplanting. A healthy crop may never be taken without planting healthy and disease free seedlings. Employing most advanced technology for raising healthy seedlings can increase the productivity of vegetables.

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Chapter 19

Breeding Strategies for Raising Productivity in Small Millets

R. Kanchanarani[1]*, S. Thiruvarasan[1] and R. Latha[2]
[1]*Oilseeds Research Station (TNAU), Tindivanam, Tamil Nadu, India*
[2]*Agricultural Research Station, Thirupathisaram, Tamil Nadu, India*
*Email rani.kanchana@yahoo.com

Compared to other crops, small millets are drought resistant, healthy and nutritious. They need less water with wider adaptability to all types of climate and soil. Small millets are traditional and staple food for majority of poor people in India and are extensively grown in extreme conditions because of their resilience to climate changes. As the small millets are indispensable to Indian agriculture, there is increasing realization of the need to improve the productivity of these crops through modern methods of breeding. So far, a total of 240 varieties in India and 60 varieties in Tamil Nadu have been released. The ultimate goal of plant breeding is to replace with superior genotypes in farmer fields.

The All India Coordinated Small Millets Improvement Project was established in the year 1986 with head quarters at University of Agricultural Sciences, Bangalore and with 14 centres spread over the country to address research needs of small millets. With the inception of separate AICRP, research on small millets has been getting focused attention for developing varieties and other agro production and protection technologies suitable to different regions. There are finger millet germplasm with significantly higher grain calcium and protein and useful in breeding for improving quality parameters. In the secondary gene pool, *Eleusine coracana* sub sp *africana* will be of interest from the breeding point of view. This could be a useful gene source for improving tillering ability, fodder yield and quality, drought tolerance and even finger number and length. A planned pre breeding is required for introgression of characters from *E.africana* to *E. coracana* for deriving lines useful in regular breeding programs. More than 15,000 accessions of various small millets are conserved with good data base. Several superior genetic stocks are identified in each of these crops. The utilization of germplasm is poor now and careful deployment of desirable germ plasm in breeding research can bring in immense benefits in improving grain and straw yield, grain quality and composition, pest and disease résistance, drought tolerance and as well meeting the emerging needs in future. The optimum use of utilization of germplasm in small millets is the most important in future breeding activities for making notable advances in the productivity of these crops and also to make small millets competitive vis-a-vis other crop options. Based on the evaluation and geographical origin, core set of germplasm have been formulated in finger, foxtail and proso millets for improving their utilization in the crop improvement.

This included little millet variety Co 1 (1954); foxtail millet varieties Co1, Co2, Co 3 (1943), H1, H2 (1948), T4 (1949); kodo millet varieties PLR 1(1942, T 2 (1949), Co 1 (1953), proso millet variety Co 1 (1954) and barnyard millet varieties T 46, T25 (1949). During fifties, with food production remaining stagnant and with raising population the importance of millet crops to Indian agriculture started gaining recognition, as they formed the important constituents of dry land agriculture. Project for intensification of research on cotton, oil seeds and millets was launched during this

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period with several centres working on millets, The importance of genetic resources as primary raw material for crop improvement was recognized prior to initiation of coordinated project and the first attempt to collect the germplasm of millets in the country was made in 1961 under the PL 480 project on “storage, Maintenance and distribution of millets germplasm “resulted in the collection of nearly 3000 genetic stocks of various small millets _718, finger millet,584 in kodo millet,431 9 in little millet,615 in foxtail millet 250 in proso millet and 399 in barnyard millet.

Crop improvement efforts during coordinated project era

Small millets have always been of local and regional importance and as a result have attracted little attention both at national and International level. Millets in general started receiving with attention with the launching of All India Coordinated Millets Improvement Project (AICMIP) in 1969. In this project small millets also started receiving some attention at a selected few centres. Small millets improvement received the major boost during 1978-79 with the establishment of five crop specific lead research centres in the country under IDRC assistance. They were Almora in Uttarakhand (barn yard millet), Dholi in Bihar (proso millet), Dindori in Madhya Pradesh (Kodo millet), Semiliguda in Orissa (Little millet) and Nandyal in Andhra Pradesh (foxtail millet.) in this project finger millet was not included as it was already receiving some attention in the Coordinated Millets Improvement Project. The IDRC project continued till 1985 and the “All India Coordinated Small Millets Improvement Project” (AICSMIP) was established in the year 1986 with head quarters at The University of Agricultural Sciences, Bangalore. The centres that were functioning under IDRC project became part of AICSMIP. There are 14 centres functioning under AICSMIP spread all over the country to address to the research needs of small millets. Small millets are known for their suitability to dry land areas, hill and tribal agriculture and contribute to food and nutritional security of the disadvantaged regions. The research in the project is focused to state / regional needs from the point of developing appropriate varietal and agro production technology for maximizing production / productivity. The work is multi-disciplinary and applied in nature. In foxtail millet, new sources of dwarfing controlled by oligo genes have e been identified (Dinesh Kumar *et al,* 1992). These accessions are useful in breeding dwarf foxtail millet similar to the ones available in wheat. The variability available for protein content (7.176-15.73) and seed fat content (4.0-7.1) in foxtail millet is enormous and can be exploited directly and useful in breeding.

Germplasm availability

In the past small millets scientists hardly had access to germplasm and worked with a handful of local collections which lacked diversity. This blunted the opportunities for of yield improvement through breeding. This situation was to some extent rectified in the 1960 when first attempts were made by ICAR to pool the collections under PL 480 project as mentioned earlier. The conservation activities further gained momentum with NBPGR, New Delhi, playing a key role in augmenting the small millets collection. Recognizing the importance and conservation and easy access to germplasm, AICMIP established a separate germplasm unit at Bangalore in 1979. This unit since then has been making efforts to collect as well as pool the available germplasm from various sources and make it available to breeders in the country. This unit is also recognized as National Active Germplasm Site (NAGS) by ICAR/NBPGR and has the mandate to assist in collection, conservation, evaluation and documentation of small millets germplasm in the country (Seetharam, 2006). Presently the unit at Bangalore is maintaining one of the largest collections of more than 15000 accessions of 6 small millets (7122 in finger millet,2821 foxtail millet,1537 kodo millet,939 proso millet,1657 little millet and 988 barnyard millet)in the country (AICSMIP, 2012).

Utilization of germplasm

The full utilization of germplasm depends on two factors: (1) evaluation and characterization and (2) identification of useful gene sources. These two areas have received considerable attention during the last 25 years and majority of the accessions have been screened for agronomic, physiological, pathological and even important grain quality parameters. The breeding value of many accessions has been judged by growing in field trials more than once. There is good data base available for most accessions and germplasm catalogues have been brought out (Seetharam *et al* 2006). In order to improve the efficiency for utilization of germplasm, core subsets have been formed and made available to breeders working at different centres. Selected germplasm have also been evaluated in the all India testing network and a number of superior accessions were identified and a couple of them have been released for general cultivation in different parts of the country. The exotic collections especially from Africa in finger millet have been largely used in recombination breeding resulting in release of many superior high yielding varieties in many states. The African germplasm have thick stem, dark leaves, robust growth, large ears, and high grain density and source of resistance to blast disease (Naik *et al,* 1993). Hybridization between African and Indian elite varieties has been highly rewarding and has resulted in the release of many high yielding varieties in the country (Seetharam, 1998). Several useful genetic stocks have been identified in all small millets accessions possessing higher protein, desirable agronomic attributes with high carbon dioxide fixation and low leaf area suitable for rain fed situations, and genotypes which can germinate under limited moisture under hard soil crust have been identified (Sashidar *et al*,1983,1986; Seetharam *et al,*1984; B.T.S. Gowda *et al*. 1986). Long glume types with higher ear photosynthesis reflecting in higher seed size and weight will be of interest in improving yield of finger millet in the coming years (Sashidar *et al,* 1983). Accessions capable of producing higher biomass, dual purpose types with superior stover quality are available for improving grain and Stover yield of cultivars. Identification several sources of stable resistance to blast disease of finger millet and their deployment in breeding research has been highly rewarding in evolution of high yielding blast resistant cultivars in finger millet in the country (B.T.S.Gowda *et al,*1986; Ravikumar *et al,*1990,1991; Seetharam and Ravikumar, 1993; Byre gowda *et al*,1998,1999). (Laxminarayana *et al,* 1983). There is variability available for Stover quality parameters as well as quantity in the germ plasm of various small millets offering scope for the improvement of feed value of crop residues (Schiere *et al*, 2004; Subba Rao *et al*, 1995).

Out come of crop improvement

The search for genetic male sterility in finger millet has been successful and now available for use. The modern finger millet varieties has the genetic potential if 5-6 tones/ha under optimum management. On the same lines recombination breeding has resulted in release of many superior varieties in foxtail, proso and barnyard millets also. The success of GPU-28 variety of ragi in Karnataka is a best example in harnessing the benefits of a good seed production and distribution program involving line departments like Karnataka State Seed Corporation Limited and Karnataka State Department of Agriculture. The package of practices for cultivation different small millets such as time of sowing/planting, choice of varieties, time and method of application of fertilizers have been developed for different regions, of the country. Management practices for aberrant weather conditions for mitigating early, mid and late season drought have been worked out. Remunerative cropping systems involving different pulse crops in millet for different regions have been evolved. Plant protection measures to control economically important diseases and pests have been evolved. Future needs after years of neglect, small millets are finding a place in agricultural research, agendas in many institutions. They are increasingly being recommended by doctors and nutritionists as being important in health management. A couple of elite food chains have begun selling millets and millets based products on their shelves as health food. The productivity of these crops which is very low compared to other major food grains could be increased by 20-50% by just adopting improved varieties in a big way. Since the seed rate is low for these crops (10 to 12 kg/ha) the extra expenditure incurred on seeds of high yielding varieties is not more than Rs.100 per hectare and could be considered as low cost technology with immence benefits. The harnessing of yield advantages from these improved varieties is the need of the hour in order to make small millets cultivation competitive and economically viable. The germplasm availability has vastly improved with the launching of AICSMIP. More than 15,000 accessions of various small millets are conserved with good data base. Several superior genetic stocks are identified in each of these crops.

The utilization of germplasm is poor now and careful deployment of desirable germlplasm in breeding research can bring in immense benefits in improving grain and straw yield, grain quality and composition, pest and disease résistance, drought tolerance and as well meeting the emerging needs in future. The rate of genetic advancement being made now barring finger millet is slow in all small millets. The realizable genetic potential is much lower compared to other dry land crops. As a result, these crops are lagging behind and getting more and more marginalized year after year. This trend needs to be reversed and breeders should intensify efforts to improve productivity along with resilience to adjust to adverse climates which is unique to small millets.

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Chapter 20

Role of Food Processing in Agribusiness

Manpreet Kaur and Ramandeep Singh
School of Business Studies, PAU, Ludhiana, Punjab

Abstract

The food processing sector in India plays crucial role as it fosters vital connections between the two economic pillars agriculture and industry. A recent phenomenon includes the transformation of agriculture through the development of forward and backward links with industry. The food processing sector is claiming a special place in the Indian economy because of its ability to create employment opportunities, raise farmer incomes, and expand exports. For the rural economy to thrive inclusively, the focus on value addition in the agriculture sector is crucial. As the result various technological advancements in food processing such as high-pressure processing, Pulsed Electric fields, ultrasound and plasma treatment have emerged. The food processing industry have revolutionary changes due to adoption of emerging technologies. Therefore, significant development of food processing industry will lead to improvement in both the social and physical infrastructure of rural India. However, some factors that prevent industries from utilising emerging technologies includes high investment, low-quality equipment, lack of scientific data and funding. This chapter discusses the need for the food processing, advancements in food processing technology, its challenges and future.

Key words : *Agri-busines, Food processing industry, agri-foods, value addition, processed foods.*

Introduction

Food products are processed for a variety of purposes. After harvest, cereals have been dried for their increased shelf life since the dawn of time. Foods were initially treated largely to increase digestibility and palatability as well as to guarantee a steady supply. Pickles, murabbas and papads are a few examples of preserved foods created in India from particular fruits, vegetables, and grains. The needs of customers have changed over time due to better communication, transportation, and industrialization, and there is now a greater demand for "fresh" and "organic" foods, "safer and healthier" meals, and foods with a sufficient shelf life. Consumers need higher-quality food that retains nutrients, often has a particular functional attribute or taste, texture, or consistency, is shelf-stable, and is simple to package, store, and transport. Scientists have been inspired by this to create processing processes and techniques that will produce food products that will satisfy consumer needs and wants. We all consume prepared foods. These include dishes like ready-to-eat curries, meals, snacks, and bread, as well as biscuits, bread, pickles, and papads. These dishes are produced utilizing a range of techniques and tools.

Need for food processing

India has transformed from an agriculturally deficient to an agriculturally surplus nation, necessitating the need for crop storage and processing. As a result, the Indian food industry has grown to become a significant manufacturer of processed foods, ranking sixth in terms of its size and contributing close to 6% of the country's GDP. Additionally, as a result of changes in lifestyle, rising mobility, and globalization,

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there is a greater need for a variety of items, necessitating the development of novel technology. The common deficiency problems caused by simple diets heavy in staple foods like cereal and frequently lacking in specific nutrients are widely known. In order to ensure that the minimal dietary requirements are met, "food fortification is done by adding the nutrient that is lacking in the food stuffs or condiments". Iodized salt, folic acid added to flour, vitamin A and D added to milk, and oils and fats are a few examples. The FSSAI has actually established guidelines for the fortification of common foods like salt, wheat flour, milk, and oats. Scientists have been forced to change the nutrient composition of meals due to the rising prevalence of ailments like diabetes and heart disease as well as concerns about wellness. For instance, they have used artificial sweeteners to reduce the calorie count of processed foods. Similar to how fat from ice creams is substituted with highly processed proteins that give the dessert its smooth texture without adding as much energy. Additionally, how consumers view food has evolved. The market for foods that are longer-lasting, preserve their original flavor and look, and are free of chemicals, pesticides, and preservatives is expanding quickly. All of this has elevated the value of the field of food processing and technology, and there is a great need for food technologists.

Basic concept

"Food processing is the set of methods and techniques used to transform raw ingredients into finished and semi-finished products. Food processing requires good quality raw materials from either plant and/or animal source to be converted into attractive, marketable and often long shelf-life food products".

The majority of developing nations use the principle of food processing to alter flavour, aroma, and texture to lengthen the shelf life of goods, increase their aesthetic qualities, and boost their nutritional value, despite the increased demand for new processed products, the fundamental principles of food processing remain the same for sustainable availability during the periods of shortage. The processed food businesses strive to meet consumer demands for creating a wide variety of nutrient-rich, delicious, convenient, safe, readily available, and affordable food items of the highest quality.

Food processing-A sunrise Industry

India's food ecosystem offers tremendous investment opportunities because of the alluring fiscal incentives, favorable economic policies, and promoting expansion in the food retail industry. Through the Ministry of Food Processing Industries, the Government of India (GoI) is taking all necessary steps to increase investments in the country's food processing industry (MoFPI). The umbrella PMKSY plan will receive INR 4600 crores from the Indian government through March 2026. From 2011–12 to 2020–21, the export of goods under the Ready to Eat (RTE), Ready to Cook (RTC), and Ready to Serve (RTS) divisions saw a CAGR of 10.4%. India exported finished food goods worth more than $ 2.14 billion in 2020–21. The U.S.A., U.A.E., and Nepal are the top three countries where RTE exports are going in 2020–21 statistics. USA, Malaysia, and UAE will be the top three exporting countries for RTC in 2020 and 2021. Since April 2014 through December 2021, the food processing sector has attracted $5.15 billion in FDI.

Food processing–Post harvest activity

A post-harvest activity that adds value to an agricultural product before marketing is food processing. In addition to the initial preparation of food raw materials, it also involves the packaging of fresh items, primarily horticulture and fish. The food processing sector is seen as a strategic opportunity for developing nations, offering them new revenue streams as well as the creation of employment and the internalization of cutting-edge knowledge and technology. Food processing industry has contributed 11.6% share towards the total employment and 10.4% share in india's total export.

Technologies of Food Processing

Thermal treatment : Traditional thermal treatments includes entail heating the goods for a set period of time and temperature. Thermal treatments are used to get rid of pathogens, lessen microbial deterioration, boost food safety, and prolong shelf life However, these processes can alter the goods' physicochemical, sensory, and nutritional characteristics. Food manufacturers look for alternatives in food-processing technology in order to lessen the potential detrimental effects of conventional thermal treatments on food qualities.

Non-Thermal technologies

High pressure processing : High pressure (HP) is the most advanced new processing technology for gentle food preservation due to the demand for high-quality food. The packaged food is placed in a

Table-1 : Issues and Challenges in Food Processing Entrepreneurship.

Issues	Challenges
I. Agri Production	
1. Raw Materials Quality	The quality of the raw materials used in food processing is quite low, and they are handled improperly.
2. Volume of crops available	Due to post-harvest waste and inadequate storage facilities, there is an inadequate and very low quantity of raw materials available for food processing.
3. Seasonality of production	Due to the seasonality of agriculture and horticulture production, raw materials are often unavailable, and inventory carrying costs are quite high in this industry.
4. Low yield of crops	Agriculture has not been market-driven and has instead primarily been viewed as a means of ensuring human survival and providing a living for farmers. The quantity of crops that have been produced has not been sufficient or adequate for processing.
II. Infrastructure and Technology	
1. Poor access to communication and networks	Rural areas have very limited access to information and communication networks, and supply and demand problems are among the factors contributing to this.
2. Lack of equipment	Lack of resources for machine maintenance, quality control, and repairs
3. Appropriate technology/Plant access	Due to the high cost of technology, rural communities lack access to the necessary equipment and processing facilities for the processing of raw commodities.
4. Access to services	The ability to access some service facilities, such as those for storing farm produce, fumigating services, and testing laboratories, is limited in some areas.
III. Finance	
1. Cost of Production	Due to high production costs caused by low productivity, processed foods and other products are no longer competitive.
2. Investment and modernization of the food processing sector	Lack of equipment and plant availability could impede modernization and expansion in the food processing industry.
3. Inadequate structures for taxes and levies	India has the highest processed food taxes in the world, which deters innovation, R&D, and other processing techniques in this industry. Products now cost a lot more due to excessive taxes and customs, making it impossible for them to compete on the domestic and worldwide markets.
4. Poor access to credit	Companies in rural areas struggle to get finance, and they are left to rely only on their own resources, which are insufficient to maintain a profitable business.

carrier, automatically packed into the HP vessel, and the vessel valves are closed for the HP treatment. Water, which often transmits pressure, is pumped into the container from one or both ends. The pumping stops when the desired maximum pressure is reached. The popularity of HP-treated products is largely attributable to the fact that HP-treated foods keep more of their natural fresh taste, texture, and nutritional value in addition to being microbiologically safe. Consequently, these items are of higher quality than their thermally treated counterparts.

Pulsed Electric fields : Pulsed electric fields PEF is a non-thermal method of preserving food that uses brief electrical pulses to inactivate microorganisms while having a minimally negative impact on food quality characteristics. Additionally, it offers the chance to collect metabolites from cells and infuse precursors or other necessary components while retaining the vitality and productivity of the cells.

Ultrasound : The US has applied two different ways of food technology namely low energy diagnostic US in the MHz range . High power US in the kHz range applied for material alteration .Low treatment intensities and amplitudes result in acoustic streaming, whereas high intensities and amplitudes result in local pressures below the liquid's vapour pressure. As a result, the material's gas bubbles repeatedly grow and abruptly deflate (cavitate) The majority of the consequences of high power US in food processing are caused by cavitation and related phenomena.

Plasma treatment : An innovative nonthermal food processing method called cold plasma uses reactive, energetic gases to destroy contaminating bacteria on poultry, meat, vegetables and fruits. This adaptable sanitising technique only needs electricity and a carrier gas like oxygen, air, helium or nitrogen; chemical antimicrobials are not necessary. The main mechanisms of action in cold plasma ionisation process includes UV radiations and reactive chemical by products of ionisation process.

The primary drivers for businesses to employ nonthermal food-processing technology were improved nutrient and sensory quality, followed by an extension of the product shelf life and a fix for safety issues. Some factors, meanwhile, prevent some industries from utilising emerging technologies. The main deterrent to embracing emerging technology, according to reports, is the high investment. In addition, barriers include the fact that technology is still in development, low-quality equipment, a lack of scientific data and funding, and higher product prices.

Challenges in Food processing

Future of food processing industry : Indian coasts are now accessible to foreign investors and technologies thanks to globalisation. As a result, a large number of global and multinational businesses are establishing operations in our nation for production, R&D, education, and outsourcing. Therefore, there is a lot of room for food technologists and scientists in both Indian and international organisations. Additionally, the food processing sector offers excellent opportunities for product export. Additionally, job exchanges will be improved and strengthened. Revenue in the Food market amounts to US$866.70bn in 2022. The market is expected to grow annually by 8.01% (CAGR 2022-2027).The market's largest segment is the segment Bread & Cereal Products with a market volume of US$157.20bn in 2022. In the Food market, 1.0% of total revenue will be generated through online sales by 2022.In the Food market, volume is expected to amount to 663,725.9mkg by 2027. The Food market is expected to show a volume growth of 5.7% in 2023.(source: https://www.statista.com/outlook/cmo/food/india)

Conclusions

The food processing industry has the potential to play a significant role in both India's economic development and entrepreneurship. Rural economic development and national economic growth both greatly depend on food processing industry. As natural resources are abundant in India, which offers the food processing sector a competitive edge. The five main drivers which tend to influence the food processing industry are namely as: Favourable circumstances and a competitive edge in the food processing industry, increase in consumer expenditure on processed and ready-to-eat items, government support, expansion of food retailing in India. Therefore food processing industry has massive potential in India which can be exploited through strategic planning of resources and wise utilization of emerging technology which will help in eradicating poverty and employment issues from the country.

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Chapter 21

Two Decades of Bt Cotton in India

Chitti Bharatkumar, Rajesh S. Patil, Birdar. B.D and Patil P.L.
University of Agricultural Sciences, Dharwad, Karnataka

The Bt is a short form of ubiquitous soil bacterium Bacillus thuringiensis. A genotype or individual which is developed by the techniques of genetic engineering is referred to as transgenic. In other words, genetically engineered organisms are called transgenics. A transgenic may be a plant, an animal or a microbe. Transgenic plants contain foreign gene or genetically modified gene of the same species. Cotton is the first crop to receive environment clearance as GMO in Indian Agriculture, and thus it has received maximum attention from planners, scientists, social workers, media, farmers and general public. When Bt cotton was released during 2002, the area under Bt cotton was very less, 0.29 lakh hectare. Now Bt cotton occupies 117.47 lakh hectare which comprises 93.34 percent of cotton area. Which indicates that farmers were accepted Bt cotton over two decades.

India is third largest producer of cotton, with about 2.86 million tones of cotton lint produced each year and also world's largest acreage of 8.9 million hectares under cotton cultivation, In terms of average productivity, India is among the lowest with 320 Kg per hectare. The productivity ranges from 200 Kg per hectare to 600 Kg for hybrid varieties. The crop is grown in varied agro-climatic situation across nine major states viz. Maharashtra, Gujarat, Madhya Pradesh, Punjab, Haryana, Rajasthan, Andhra Pradesh, Karnataka and Tamil Nadu. The crop is also grown on small area in Orissia, Assam, U.P and West Bengal. Nearly 60 million people are engaged in cotton production, marketing and processing. The textile industry which utilizes the cotton provides employment to about 16% of the total workforce. Cotton in its various forms also serves as raw material for more than 25 industries.

Pests appear in quick succession in the various stages of growth of the cotton plant. First to infest are sucking pests like aphids and jassids, followed by white flies. It is then the turn of bollworms and by the time the crop enters the flowering stage, bugs take over. Farmers therefore use a cocktail of expensive chemical pesticides to control pest infestation. Currently pesticides account for one-third of total cultivation costs.

Increasing reliance on pesticides over the years have replaced traditional methods that include a variety of labor intensive practices like hand picking to remove pests and cultural practices like intercropping, crop rotation, and the burning or removal of cotton residue from the soil.

Intensive cultivation practices and indiscriminate use of conventional as well as fourth generation pesticides like synthetic pyrethroids have created resistance among some of the key pests, including the American bollworm. Monocropping and favorable climatic conditions in certain years have further accentuated the problem. In the early 1990s, the outbreak of leaf virus reached epidemic proportions in the northern plains The reasons for this outbreak are not fully known, however based on the experience of other countries, it is reasonable to assume that excessive use and abuse of pesticides is a major contributing factor.

Dependence on chemicals has, in some cases,

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been so heavy that farmers have had to resort to a mix of several pesticides, the so-called pesticide cocktails. And it is not uncommon to spray more than 30 times per season.

The decision of the Genetic Engineering Approval committee (GEAC) of Government of India clearing the release of Bt cotton for commercial cultivation during 2002-2003 crop season, is considered as one of the major milestones in the history of cotton improvement in India. Incidentally, cotton happens to be the first crop to receive environment clearance as GMO in Indian Agriculture, and thus has received maximum attention from planners, scientists, social workers, media, farmers and general public. With liberalization of world trade following WTO formation, quality and price competitiveness have become the buzz words not only for export performance but also for domestic use. India made significant strides in productivity since independence. The country was producing only 2.3 m bales of short and medium staple cotton from 4.4 million ha (with production of 88 kg lint / ha). With two major technological interventions viz. introduction of hybrid technology in early seventies and molecules in early eighties, productivity rose to 300 kg lint/ha. However, the protection technology has been misused and started showing negative impact, thus stagnating yields for the last 5-6 years. Today, productivity of Indian cottons is lowest in the world. In contrast, the major cotton producing countries have productivity 3 to 5 times higher. There are many reasons of low productivity of cotton in India. Besides dependency on 70% cotton production on vagaries on monsoon, diverse ecological and soil conditions, constant threat from pests and diseases is considered a major biological challenge to successful cotton productivity. Amongst the biotic stress factor, bollworms are by far the most serious pests of cotton and alternative controlling strategies, such as Bt cotton is considered a welcome technological step.

Why Bt Cotton?

In India, 162 species of insect pests attack different stages of cotton. Of these, about a dozen are major and half of them are key production constraints necessitating management interventions in the crop ecosystem. The sucking pest complex comprising of aphids, jassids, thrips and whitefly are widespread and fairly serious. However, their damage can be efficiently contained by the existing practices of cultural, chemical, biological and host resistance means. The bollworms are most important tissue feeders and highly damaging. Three types of bollworms viz. American bollworm (*Helicoverpa armigera*), Pink bollworm (*Pectionphora gossypiella*) and Spotted bollworm (*Earias vitella*), normally referred as bollworm complex are by far the most damaging and loss inducing pests of cotton. Amongst them, Helicoverpa emerged as a key pest all over the country causing as high as 80% losses in cotton.

What is Bt?

The Bt is a short form of ubiquitous soil bacterium Bacillus thuringiensis. This bacterium is gram positive and spore forming that forms parasporal crystals during stationary phase of its growth cycle. The synthesized crystalline proteins called 'endotoxins' are highly toxic to certain insects. They kill the insect by acting on the epithelium tissues of midgut of caterpillars. These proteins often appear microscopically as distinctly shaped crystals and constitute about 20-30% of dry weight of sporulated cultures. These proteins are characterized by their insecticidal activity and are therefore grouped into four classes i.e. Lepidoptera-specific (Cry I), Lepidoptera and Diptera-specific (Cry II), Coleoptera-specific (Cry III) and Diptera-specific (Cry IV). Different strains of Bt produce more than 25 different but related insecticidal crystal proteins (ICPs). These are toxic to larvae of different insects including disease vectors and many agricultural pests. Cotton bollworms belong to the order Lepidoptera and therefore are sensitive to Bt Cry I and Cry II proteins, which are specific to them. Other beneficial insects are unaffected by these proteins. The gene bank data base of Bacillus Genetic Stock Centre (BCSC) have given a list of Cry(Crystal), Cyt(Cytolytic) and Vip genes either synthetic or modified versions from B.thuringiensis. About 22 classes of Cry including 126 Cry genes have been registered along with a Crt gene and 3 Vip (Vegetative insecticidal protein) genes. But popularly and effectively utilized are Cry 1 Ac, Cry 1 Ab in different crops.

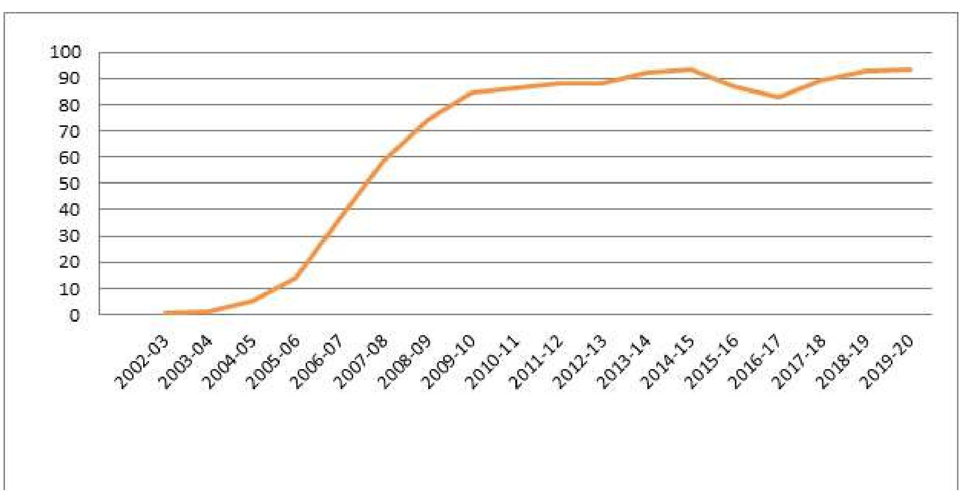
What is Bt Cotton?

A genotype or individual which is developed by the techniques of genetic engineering is referred to as transgenic. In other words, genetically engineered organisms are called transgenics. A transgenic may be a plant, an animal or a microbe. Transgenic plants contain foreign gene or genetically modified gene of the same species. The foreign gene may be from a

Years	Area under cotton (in Lakh hectare)	Area under Bt cotton (in Lakh hectare)	Production (in lakh bales)	Yield kg per hectare
2002-03	86.24	0.29	86.21	191
2003-04	75.98	0.92	137.28	307
2004-05	87.87	4.85	164.29	318
2005-06	86.78	12.34	184.99	362
2006-07	91.44	33.53	226.32	421
2007-08	94.14	54.72	258.84	467
2008-09	90.07	66.69	222.76	403
2009-10	101.32	85.52	240.22	403
2010-11	111.23	96.32	330.00	499
2011-12	121.78	107.58	352.00	491
2012-13	119.77	105.43	342.00	486
02013-14	119.60	110.35	359.02	510
2014-15	128.19	119.40	348.05	462
2015-16	122.92	106.83	300.05	415
2016-17	108.28	89.43	325.77	511
2017-18	124.29	110.76	328.05	477
2018-19	126.58	117.81	287.08	386
2019-20	125.84	117.47	322.67	436
2020-21(P)	130.07		353.84	462
2021-22(P)	120.69		362.18	510

Source : As per Meeting of the Committee on Cotton Production and Consumption (COCPC) held on 12.11.2021, P-Provisional.

(a) Area under Bt Cotton over the Years.



(b) Percent increase in the Area under Bt cotton.

distantly related species, closely related species or unrelated species or from micro-organisms such as fungi, bacteria and viruses. Bt cotton refers to transgenic cotton which contains endotoxin protein inducing gene from soil bacterium Bacillus thuringiensis. The first transgenic plant was developed in 1983 in tobacco in USA In cotton, the first transgenic plant was developed in 1987 in USA by Monsanto, Delta and Pine companies (Benedict and Altman, 2001). Later on, the research work on development of transgenic was intensified all over the globe and several transgenic plants were developed. The transgenic cotton is of two types viz. (1) bollgaurd and (2) roundup ready cotton. The former confers resistance to bollworms and the latter is resistant to herbicides. The area under herbicide resistant transgenic cotton is resticted to USA. However, bollworm resistant Bt transgenic cotton has spread to several countries. Transgenic disease resistant cottons have not yet been developed. Characterization of antifugal factors is underway at the USDA (Rajasekharan et.al.1999). In India, a few resistant genes against Fusarium and Verticillium wilts have been isolated and are being transformed into cotton. Chinese scientists have isolated 'GO' gene and have transformed them into cotton which have shown resistance to both the wilts (Zhang et.al.2000).

How Bt cotton is developed?

For development of transgenic of any crop, there are five important steps: (a) Identification of effective gene or genes, (b) Gene transfer technology, (c) Regeneration ability from protoplasts, callus or tissues, (d) Gene expression of the product at desired level, (e) Proper integration of genes so that are carried for generations by usual means of reproduction. Once identification of bollworm inhibiting genes has been achieved, molecular biologists have step by step solved the problems to achieve perfect transgenics. In case of cotton, Agrobacterium-mediated gene transfer technique has been essentially used. Although now for direct gene transfer to protoplast, biolistic gene transfer techniques are available. The regeneration of cotton plants from callus and somantic embryogenesis have so far been restricted to few 'Coker' genotypes. All cotton genotypes are not amenable to regeneration and that is one big hurdle in gene transfer. There are reports of induction of somantic embryogenesis has also been reported from china and Australia but in India, attempts to repeat it with Indian genotypes have been unsuccessful .To circumvent the problem of genotype-limited regeneration of callus or leaf tissues, transformation and regeneration from meristematic tissues was attempted which was found useful. Using Cry 1 Ab and Cry 1 Ac genes, transgenic cottons with perfect integration, expression and reproduction was achieved first in USA in 1987. Subsequently, there are reports from china and Australia. In coming years, the techniques are being invented and the problems of genotype-dependent regeneration will be sorted out.

There are four important methods of foreign gene (DNA) transfer in crop plants viz. plasmid method, particle bombardment, direct DNA uptake and micro-injection (Stewart, 1991). These methods are also known as systems of DNA delivery for genetic transformation. The soil borne bacterium Agrobacterium tumifaciens (termed as Nature's Genetic Engineering) is used for development of transgenic plants. This method has three main limitations viz. host specificity, somaclonal variation and slow generation. There are two main advantages of Agrobacterium mediated DNA transfer method. Firstly, this method has some control over the copy number and site of integration of transgene which is not possible in particle bombardment method. Secondly, this is a cheaper method of genetic transformation than particle bombardment method. Perlak *et.al.* (1991) transferred successfully the Cry 1 Ac gene to cotton via Agrobacterium with CaMV promoter and the Cry protein produces by transgenic cotton was found highly toxic to bollworms. This method was later used extensively by others. The particle bombardment method in which the foreign DNA is delivered into plant cells through high velocity metal particles, has some advantages over the Agrobacterium mediated method of DNA transfer, This method does not exhibit host specificity. Hence, it can be effectively used for the development of transgenic plants in various plant species. Moreover, this method is technically simple than Agrobacterium mediated DNA transfer method. In this method, there is no need of isolating protoplast. The other two method viz. direct DNA transfer and microinjection technique are rarely used for developing transgenics in cotton. Currently, two DNA delivery system, viz. (1) Agrobacterium mediated gene transfer, and (2) bombardment of cells with plasmid DNA coated particles, are widely used for development of transgenic (genetically engineered) plants in cotton (Umbeck *et.al.,* 1987; Firoozbady *et. al.,* 1987; Finer and McMullen, 1990). The first two workers used Agrobacterium method while the last workers used biolistic method of gene transfer in cotton for developing transgenic plants. More than 37 transgenic plants have been developed in cotton so far by these two methods (Mayee *et al.,* 2002).

How is Bt cotton different from conventionally bred cotton?

The scientific basis of plant breeding was established soon after the discovery of Mendel's laws of genetics. The basic concept of plant genetics is that the traits/characters are controlled by genes that genes are located on discrete structure called chromosomes located in the nucleus of each cell of an organism, and that mixing or recombination of parental genes occurs during the formation of sex cells in the first generation progeny. The number of different chromosomes in a cell is specific to the species. For example, in Upland cotton i.e. *G. hirsutum* and Egyptian cotton *(G. barbadense)* which are tetraplodis have 52 chromosomes while in the Indian diploid desi cottons, *G. arboreum, G. herbaceum*, the chromosome number is 26. In a normal plant, two copies of each chromosome are present. One set of chromosomes (say 26 in *G. hirsutum*) is contributed by a male parent and one set by the female parent. Two copies of each chromosome means that each gene is present in at least two copies, although many genes may be present in multiple copies in the genome. A plant trait controlled by one gene pair such as fibre colour is called qualitative trait. However, most of the characters of agronomic or economic importance are quatitative and controlled by the interaction of many genes. For most traits different versions of the controlling genes exist. It is this diversity of gene type that provides the basis of traditional plant breeding. The breeder attempts to introduce a large number of genes (desirable) from a range of different genetic sources into a single superior genotype. Traditionally, it is done by sexual hybridization. Thus, gene transfer is limited to plants that are sexually compatible. While selecting for traits, a breeder has to eliminate the unwanted genes contributed by donor parent and thus involves the process of backcross, intercross, self pollination strategies and selections. Traditional breeding deals with large blocks of DNA and of tern a long drawn process to achieve breakage of undesirable linkages, intense scrutiny to identify 'recombinant plants' containing only useful genes. These methods have been useful in enhancing the yield potential by more than 200 kg lint per ha in India on an average. Traditional breeding has also limited use in evolving bollworm-resistant cultivars as no precise sources of donors within compatible types are available for large scale breeding. Genetic Engineering (GE) is a breeding strategy that attempts to avoid the problems associated with the transfer of large blocks of genetic material between two parents. The current state of technologies allows only a very limited number of foreign genes (from any life source) at a time to be introduced into a plant. However, single gene traits cause least disruption of the existing plant genome and are much easier to develop in subsequent breeding efforts. Two components are required to accomplish genetic engineering. The first is the knowledge of plant genomic structure and the structure of a single gene, and the second is the ability to develop a complete plant from a single cell (regeneration). Not all varieties can be regenerated so direct GE is limited to a few that can be. These are unfortunately not agronomically superior and hence a series of backcrossing and selection is required to put the new gene into the best varieties. Genes are composed of DNA, a linear series of four basic chemical subunits. The linear order of these subunits determines the regulation and expression of genes. Each chromosome consists of one exceptionally long double stranded DNA molecule, and the genes are arranged linearly along the strand, usually with long stretches of non-functional DNA sequence, each with a different function, (1) a sequence at the start of gene called promoter, dictates when, where and how much of the gene product will be produced, (2) a central region, called the coding region, provides the genetic code for the gene product, and (3) a terminal region, where the gene ends. The final product of the gene, with few exception, is generally a protein. The function of each gene / protein is specific, but collectively these functions range from nutrition storage and cell structure to metabolic catalysts (enzymes) and plant defensive agents. Protein with latter functions are used in Bt cotton lines. In reality, individual plant cell are 'transformed' by insertion of foreign DNA. Various techniques are available to do this, but the most common method relies on a system provided by nature. The bacterium causing the crown gall disease Agrobacterium tumefaciens is nature's own genetic engineer. It transfers some of its own DNA to plant cell as a part of the disease process. Scientists have removed the 'disease causing DNA' part from selected bacterial strains and discovered that the bacteria, while no longer causing the crown gall disease, retain the ability to transfer to a plant cell any DNA' that was removed.

This natural system thus allows any gene to be transferred to a plant cell through this bacterium. Since the specific site on chromosome where new DNA is inserted into an existing gene, it is necessary to do many transformations and regeneration events and then select the transgenic plant that gives the best performance. This is called Agrobacterium-mediated gene transfer. There are other methods of gene transfer available now, such as direct gene transfer to protoplasts and biolistic gene transfer where bombardment of regenerable tissues with DNA coated microprojectiles at a very high velocity is used for ingestion of foreign genes into plant cells. Traditional breeding methods deal with blocks of chromosomes based on sexual hybridization and recombination. GE deals with a very limited number of defined genes designed to impart traits to a crop that are not present in the traditional germplasm breeding pool (Mayee *et al.,* 2002).

Impact of Bt cotton over the years

Area, production and productivity of Bt. cotton have increased steadily since its introduction in India, barring minor fluctuation in few years. Details of year-wise area under cotton, Bt. cotton, production and yield of cotton during 2002-03 to 2019-20 is below:

When Bt cotton was released during 2002, the area under Bt cotton was very less, 0.29 lakh hectare. Now Bt cotton occupies 117.47 lakh hectare which comprises 93.34 percent of cotton area. Which indicates that farmers were accepted Bt cotton over the years.

Import and Export of cotton: 3rd largest exporter of cotton with estimated export of 45 lakh bales (0.76 Million MT) i.e. 8% of world export of 597 lakh bales (10.15 Million MT) in 2021-22. Although India is a leading producer and exporter of cotton, some quantity i.e. less than 10% of the total consumption of cotton in India is imported by the textile industry to meet their specific requirement. The following table gives the import and export figures for the last 5 years :

Year	Import (in lakh bales)	Export (in lakh bales)
2016-17	30.94	58.21
2017-18	15.80	67.59
2018-19	35.37	43.55
2019-20	15.50	47.04
2020-21(P)	11.03	77.59
2021-22(P)	10.50	45.00

Source : As per Meeting of the Committee on Cotton Production and Consumption (COCPC) held on 12.11.2021, P-Provisional.

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Chapter 22

Indigenous Technical Knowledge (ITK) Based Insect Pest Management : An Indian Scenario

Rohit Rana[1]*, Ipsita Samal[2], Tanmaya Kumar Bhoi[3], Deepak Kumar Mahanta[4], J. Komal[5] and Princi[6]
[1]*Department of Entomology, Rashtriya Kisan (P.G.) College, Shamli, (U.P.), India*
[2]*Department of Entomology, Sri Sri University, Cuttack, Orrisa, India*
[3]*Forest Protection Division, Arid Forest Research Institute, Jodhpur, Rajasthan, India*
[4]*Department of Entomology, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India*
[5]*Department of Entomology, Navsari Agricultural University, Navsari, Gujarat, India*
[6]*Department of Botany, Jamia Hamdard, New Delhi, India*
**Email* : rohitrana.ent@gmail.com

Abstract

Farmers require pest management in order to feed India's expanding population. Pesticides aid in the feeding of 1.27 billion people. Agricultural inputs such as artificial fertilisers and synthetic pesticides were expanded during the green revolution in 1966. Pesticide misuse has thus resulted in substantial environmental and health damage. Pesticides also have a negative impact on soil nitrification microorganisms. Pesticides have a negative impact on tritrophic interactions, food chains, and food webs by affecting beneficial soil bacteria, natural enemies of insect pests, fish, birds, and other animals. Indian farming is dynamic, therefore local technological knowledge for sustainable agriculture will steadily change pest management. In this context, Indigenous Technical Knowledge (ITK)-based crop protection methods can replace pesticides and restore natural enemy biodiversity, shaping the tritrophic interaction. However, as a knowledge-based and farmer-driven approach, farmers must be educated to use IPM-related control measures efficiently. ITK related to plant protection in agriculture will replace chemical control and help achieve sustainable crop production and protection. For sustainable agricultural production, small and large-scale (ITK)-based products production is economically viable.

Key words : *Pest management, indigenous technical knowledge, agricultural production, economically viable.*

Introduction

Agriculture is a crucial part of Indian economy and to feed the burgeoning population of India, farmers have to be dependent on various pest management tactics. Out of which, pesticides play a very important role in ensuring food security for more than 1.27 billion population. After the green revolution in 1966, the use of external inputs like chemical fertilizers and synthetic pesticides in agriculture increased more than hundred times[17]. Thus the injudicious and indiscriminate use of pesticides has resulted in tremendous loss to environment and human health. Furthermore, pesticides have also been reported to adversely affect the microorganisms in soil responsible for nitrification[27]. Along with the target, pesticides also affect beneficial soil microorganisms, natural enemies to insect pests, fish, birds and other wildlife, thus adversely affecting the tritrophic interactions, food

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chains and food webs directly and indirectly. Even the produces i.e., the crops are not free of contamination because these crops retain some amount of toxins even after the harvesting is done and sometimes due to biomagnifications the concentration of the toxicants also increase in the higher trophic levels. These crops/animals act as the slow poison for us both human beings and animals. Upon consumption of such produces human suffer several diseases like fatigue, brain disorder, skin diseases, blood disorder, liver and kidney damage, nausea, reproductive damage, breathing problems and cancer. Farmers, the direct victim of this on contact to the pesticides at the time of using or spraying pesticides are at the greatest risk because there is every possibility of absorbing toxic level directly into their bodies. In this regard there is a necessity to use the old traditional practices in a suitable manner to prevent insect pest infestation[36]. Traditional agriculture is the connecting step between the local hunt and gather practices which provide subsistence food to the growing population. It is basically a balance between our present needs, conserving natural resources and finally protecting the existing environment for the benefit of future generation[1]. Thus identification, utilization and documentation of these traditional knowledge from the traditional and elderly people can essentially bridge the gap between advanced current science and the traditional age-old practices. Indigenous knowledge with various levels of refinements can effectively act as a source of sustainable agriculture. By using the traditional knowledge, the crop losses due to both biotic and abiotic stresses can be minimized without harming the environment and its ecological viability[2]. Furthermore, various problems related to pesticide use, such as careless use of pesticides which leads to development of resistance, resurgence and residue problems, such problems can be minimized by using this traditional knowledge. Most of these traditional strategies are full proof and target pest specific[24].

ITK based pest management practices

Some traditional and new knowledge in relation to the aforementioned categories that is important for acceptability in IPM techniques has been evaluated and presented in the following sections.

Traditional pest management practices in rice : Rice is one of the most important crops in Indian economy and knowledge of these traditional practices are helpful in managing various major and minor pests of rice[54]. For managing rice pests, the suspension of raw cow dung and water is used for spraying in rice field to control thrips (*Thrips oryzae*)[18]. Another method of erecting the bamboo sticks in the rice fields prevents infestation of rice yellow stem borer (*Scirpophaga incertulas*) and swarming caterpillar (*Spodoptera mauritiana*)[29]. Bamboo sticks attract the predatory birds to take rest and ultimately the birds have been reported to feed both on the larvae and adults of swarming caterpillar and the yellow stem borer. Moreover, the sap of bamboo sticks has been observed to contain an antiseptic compound, hydrocyanic acid which has repellant properties against the sap feeders and various stem borers of rice. Apart from this the neem decoction (*Azadirachta indica* A. Juss.) of seeds, leaves and stem has been reported to control the rice yellow stem borer[33]. The extract was prepared by mixing 1 to 3 gm of ground neem seed/leaf in 1 l of water (0.1-0.3% concentration) for 12 hrs. The azadirachtin in neem plant is having growth and feeding deterrent properties to insects[44]. Furthermore, the kerosene dipped rope is dragged in rice field to control rice case worm, *Nymphulla depunctata* as kerosene acts as a toxicant against case worm. Moreover, raw cow dung is mixed with water to control case worm in rice as it creates an oxygen deficient condition in rice field, thus creates unsuitable condition for the insects to survive[5]. Proper sanitation of fields such as removal of grassy weeds from field bunds have been reported to control leaf folder, *Cnaphalocrosis medinalis* as the insects are unable to find any alternate host or microhabitat for their survival[4]. The slices of Pummello, *Citrus grandis* are kept in rice fields to control yellow stem borer. The chopped leaves of Indian rhododendron or phutuka (*Melastoma malabathricum* Linn.) has repellent activity against yellow stem borer. Hispa (*Dicladispa armigera*) in rice fields can be controlled by rearing ducks in paddy fields. Addition of cow dung which is a source of nitrogen in rice field controls the infestation of hispa[16]. The grounded bark of drumstick (*Moringa oleifera* Lam.) having medicinal properties also reported to reduce the yellow stem borer infestation. Placing branches of fern (Cybotium sp.) of fern and burying the barb fish (Puntius sp.) in the soil for 15-20 days and spraying water extracts and spraying of goat dung in the rice field controls pests of rice. Furthermore, burning of bicycle tyres in rice fields before the panicle initiation and use of fermented snail bait has been observed to repel the gundhi bug (*Leptocorisa acuta*) population in rice[48]. Putting of cycle tyre tube in the mouth of rodent burrow controls the rodent population in rice as the tyre appears like snake. Furthermore, pouring of vermilion water in the trapped rodent and releasing in the field also controls the rodent[39].

Traditional pest management practices for stored grain pests : Kothi is rectangular mud structure used for the storage of grains like wheat, maize, paddy. Kothies are covered from the top and have a small window of about 60 cm ? 60 cm square from where grains are stored[31]. They have an opening at the base to take out grains. Kuthla is a small and cylindrical/ rectangular in structure is also commonly seen in this area. It is open from the top and generally covered with a lid. Kuthla may have partition in between to store two things at a time like wheat and maize flour[58]. Kothies are fixed structures inside the room or in a courtyard whereas; kuthlas may or may not be fixed depending upon their size. These mud structures are prepared from loamy soil in which some amount of wheat straw is mixed which acts as a binding agent. The wheat straw and soil is soaked for two days after mixing properly to prepare uniform and thick mud mixture for construction of kothies and kuthlas. Lakolu is a fixed storage structure, which is planned at the time of construction of house. This structure is constructed in the centre of a wall of a room in such a way that it is out of reach of rodents and stored material is easily accessible. Peru is a traditional bamboo structure, which is used for storage of grains. Peru is cylindrical or oval in shape. The basic material used to make peru is a special variety of bamboo called Magar. It is preferred to harvest bamboo in the month of December and January to ensure durability of bamboo structures (Channal et al., 2004). Chabri is a basket with a lid, made of 2.5 cm wide bamboo strips interwoven in mat form and is circular in shape especially used for seed storage. Peti is a wooden box called Peti is used for the storage of grains in hilly areas of Shimla, Kullu. Kuthar is a traditional wooden outdoor structure locally called as Kuthar is used for the storage of multiple crops at a time[32].

Indigenous practices for pulses : Certain post harvest practices such as sun drying of pulses, cleaning of harvested produce and packaging in gunny bags are done to repel the storage pests. Certain weed plants such as *Naithulasi* (*Ocimum* sp.) and chilli fruits (*Capsicum annuum* Linn.) are kept with pulse grains to get protection from storage pests like pulse beetle, lesser grain borer, flour beetles, etc. This type of practices are eco-friendly and effective in controlling storage pests up to 60%. Furthermore, shelf life of stored pulse grains has been observed to increase up to 2 years by this practice. This practice can also be widely practised by small and marginal farmers. In certain conditions dried neem leaves are used to store grains effectively. Moreover, neem leaves are having insecticidal properties that repel insects. This cost effective and environmental friendly methods is used throughout India especially in north-eastern parts. In some parts of India, bamboo baskets are used to store pulses in the layers of sand. Internally the bamboo baskets are plastered with mud to provide unaerated conditions. Prior to storage, the grains were properly sun dried. Sun drying increases the efficiency of grains up to 80%. In certain pockets, coconut oil is mixed with black gram and green gram and tin or plastic containers are used for storage. About 50 ml of oil for treating 1 kg of pulse seeds control the bruchid infestation up to 6-8 months. As major insects of pulses such as Bruchids and pod borers prefer whole grains so storage of splitted grains are more preferred. 3-4 mins frying of grains in iron pans prevent the Bruchid infestation. Apart from this, red earth treatment of pulses in 1:1 ratio followed by sun drying for 2-3 days is also helpful in preventing Bruchid attack. Small gravels present in red earth has been observed to injure the insects and they die. Mixing of grains with ash content before storage, also reported to prevent the storage pest infestation. The sap feeders, beetles and other borers can be prevented by sprinkling of ash in vegetable fields. This practice is very effective in okra, onion, brinjal, tomato and cucumber against the leaf defoliating insects, pumpkin beetle, hadda beetle, leaf miner, thrips and aphids[35]. The mixture of cow urine, hing and nirgandhi in proper concentration has been reported to effective against insect pests of wheat. Leaf decoction of nirgundhi (30-40 leaves in 10 litres of water), was observed to have repellent properties against insects. This mixture is boiled properly to 1 litre and hing 10 gm is mixed with this and with the above mixture, 5 litre of cow urine is mixed and sprayed mainly in paddy and wheat crops. The fresh mixture of ash, soil and cow urine is used for the control of insect pests in cabbage. Dried cow dung and ash is used in field before sowing. Fresh cow urine is kept underground in earthen pots for fermentation for 8-10 days and it is mixed with 1 litre of water and finally sprayed in cabbage for control of cabbage aphid. The mixture of *Aloe barbadensis*, *Nicotiana tabacum*, *Azadirachta indica* and *Sapindus trifoliatus* controls the mustard pests in various regions of India. Leaf decoction of 1 kg gwarpatha and 200 gms of nicotiana powder is prepared in 5 litres of water and it is boiled 2-3 hours to make 2 litre decoction. Neem leaf extracts of 200 gms is mixed after evaporation and 50 gm of aritha powder is added to the above solution.

This mixture is sprayed in mustard crops for the control of pests in 2-3 weeks interval. The mixture of tobacco powder (200 gms), whey (2 litres) and aloe (2 leaves) are dissolved in 15 litres of water. The solution is left undisturbed for 15 days and finally sprayed in infested crops in 2-3 weeks interval. The brooms prepared by *Vitex nengudo*, is used for sweeping in the paddy crop, which acts as an insecticide and enhance the paddy growth. The cattle litter (dung and urine) is used to control insect pests.

Traditional management practices for pests, nematodes and crop diseases : Termite is the major pest in sugarcane plantation. The dipping of sugarcane sets in *Calotropis procera* leaf extract used @ 15% and 20% solution by was found effective in controlling termite (*Odontotermes obesus* Rambur)[46]. Furthermore, before sowing, the soil was sprinkled with 2.0 % solution of plant extract, and finally the setts were covered with soil was observed to be effective against the termite in sugarcane[1]. Plant material was soaked in water for 24 hours and followed by filtration and pouring on the soil infested with termites was also observed to be effective against severe termite infestation. This traditional method of termite control was widely practised by 25-30% farmers of Gujurat[15]. Furthermore, chopped leaves of approximately 5 kg each of *Calotropis procera* and Keemp (*Leptadenia pyrotechnica)* were put into an earthen pot. This mixture was further added with about 1 kg of salt and 10 litres of urine. The final mixture was kept in an air tight container and stored in a manure pit for 15-20 days. The final mixture, after being stored for around 2 weeks the suspension was filtered by using a cotton cloth and the final filtrate was applied along with irrigation water as an insecticide. 10 litre of suspension is enough to control termites in 1 ha. This termite control practice is widely used in Rajastan[47]. another method of termite control is used in Pondicherry and Makarbili village of Nuapada district, Odisha. In this method, *Calotropis procera* leaves were soaked in water for two days, followed by dilution and filtration and is then finally applied at the place of termite attack [55,56]. Furthermore, another cost effective method of termite control is soaking of about 8-10 kg plant material in water for 24 hrs and this soaked mixture is finally processed, boiled and filtered, and the final extract is poured on the infested soil to kill termites[37].

In certain pockets of Rajasthan, farmers keep the plant twigs along with about 50 gm urea and 1 l water in earthen pot, and the mixture is sealed airtight by plastering its mouth with clay soil. This container was stored in a manure pit for 2 months. Within 2 months period, the twigs were observed to decompose completely and the filtered extract is used for seed treatment of wheat, barley and chickpea. The infestation was observed to be minimised by this treatments. Furthermore, the same extract was also observed to control earthworms in ornamental plants[45]. Moreover, the leaves of *Calotropis procera* when placed in paddy fields attract aphids. Long branches of the former plant were placed at a distance of 14.6 m in paddy fields; around 25-30 branches are required for 0.24 ha. The branches are changed thrice during which life span of aphids come to an end. This method was widely practiced in Gujurat[41]. In certain places of Karnataka, *Calotropis procera* branches are placed at the water inlet of paddy fields to control insect pests. There is an alkaloid present in the latex of this plant which is having repellent properties against the stem and root borers[4]. Furthermore, Whole Calotropis plant leaving the root part is ground and is placed at the irrigation channel. When the plant extract is flowed along with the irrigation water it controls the root and stem borers. In Mehsana area of Gujarat, farmers were observed to spread the whole leaves of the standing crops which was acting as an attractant for the army worm. The insects gathered on the broadcasted leaves are collected next day. This is also a cost effective method of pest control. Furthermore, leaves are replaced regularly and the collected leaves are destroyed[42] .Some farmers of Pudupatti, Tamil Nadu were observed to use the plant parts to control the brown plant hopper in the affected fields. This leaves are used both in nurseries and main fields to control brown plant hoppers. The latex of *Calotropis gigantea* was diluted with 15 parts of water and the final dilution was sprayed on cotton crops. This method controls caterpillars within three days. This is in practice of Bhavnagar area of Gujarat[30]. Farmers from Medak and Nalgonda districts of Andhra Pradesh were used to spread twigs on field boundaries to control red hairy caterpillar migration in groundnut fields. The alkaloid emanating from this plant was observed to have repellent properties against the bands of red hairy caterpillar[52]. Furthermore the smell of the latex of twigs were also observed to have attractant properties against the red hairy caterpillar in groundnut, castor and sesamum in rainy season. Finally the larvae are collected and burnt. This method of vegetative trapping is more beneficial and economically feasible than the trapping methods by using pheromone traps and light traps[34]. Furthermore, Galo disease of sugarcane which is identified by deposition of sticky droplets, semi-liquid honey like dew on the leaves and stems can be cured by using the leaf extracts. Before winter, the farmers used to collect the Calotropis twigs and soak them in a tank for 1 month. The decayed extract was then sprayed on sugarcane plantation which has been observed to cure the galo disease within 2-3 days. But before consumption, the setts of sugarcane should be washed properly[23]. In Surendra Nagar area of Gujarat, leaves of *Calotropis procera*, neem and aloe (*Aloe vera*) are ground in equal parts and a homogenous mixture is prepared. This mixture (500 ml of the plant extract with 5 gm of washing powder, diluted in 15 L water) is applied in 30 days old cumin crop, at 8 –10 days regular intervals to prevent blight disease[41]. Ginger (*Zingiber officinale* Rosc.) can be protected from the attack of insect pests by planting *Calotropis* sp. randomly in the fields. The smell from the plant repels the insect pests. This is practised in parts of Gujarat[38]. Moreover, the aqueous leaf extract of planting *Calotropis* sp. can be sprayed @ 1% within 40 days of germination (two sprays) was well reported to reduce the groundnut bud necrosis disease[49]. The leaf powder was applied @ 50 kg/ha in mustard crop was reported to control mustard saw fly (*Athalia proxima*) effectively. Furthermore, soil application of leaf powder (@ 100 kg/ha) has been observed to reduce root knot nematode infestation in pigeon pea[50]. To increase the arecanut and coconut yield, the Calotropis plant pieces (25-45 kg) were applied in soil in circular manner. There is a common belief among farmers that if natural oozing or gum secreting plants are applied to arecanut or coconut palms, it will naturally increase the palm yield[40].

Traditional pest management practices in southern India : Major pests of coconut plantations are from 3 species including 2 from Coleoptera and 1 from Lepidoptera. The *Rhinoceros beetle* (Coleoptera) causes major damage to coconut plant by boring into the unopened tender ponds, chewing the fibrous plant materials and sucking the juice from the fibrous material. The damage is observed as a sequential series of holes in the leaves when they open and ultimately the plant dries out. Another insect from Coleoptera, the red palm weevil in early stages was observed to feed on soft plant tissues and often cause serious damage in coconut plantations. Furthermore, the black headed caterpillar, a Lepidopteran pest was observed to feed on the green plant parts and affect the productivity of the plant adversely. Certain plant materials directly or indirectly are used as pesticides as well as fertilisers. Fly ash and lime are used as best remedies for pest control. Different types of traps such as firetrap, pot trap, meat trap, sand trap and plant trap are used for pest control in paddy fields and coconut plantations. For attracting moths, fly traps are used by indigenous farmers by using glowing flames. The moths which are attracted towards the flames are killed. These type of traps are very effective against stem borers. Meat baits are prepared by using fresh water crabs to prevent rodent infestation. The abdominal part of the female crab, thelycum region was filled with plant based poison such as (*Croton tigliuum*) and used as meat traps. Apart from some natural attraction traps, bird perches are also used to attract predators such as birds. The attracted birds will kill the larvae and adults of various insects and rodents in field[19]. A bird scarcer such as a white cloth hanging is used to scare away Egret that cause damage to paddy crops in fields. Furthermore, Palmyra palm leaves are used to repel the rodents in rice field and coconut plantations (*Borassus flabellifer* Linn.) scares away the rodents[7]. Mostly the traditional practices are used along with advanced methods of pest control. mostly lime and fly ash is commonly used for controlling insect pest in the agricultural fields[8]. Fly ash when dispersed in paddy field kills microbes and other insect pests. Fly ash along with lime dispersed on coconut plants[9,10], deters *Oryctes rhinoceros* and *Rhynchophorus ferugineus* (Red palm weevil)[11,12,13,14,20]. *Azadirachta indica* seed and leaf extracts are used to prevent yellow stem borer attack in paddy fields[7,8,22]. *Pongamia pinnata* Pierre was also observed to have insect deterrent properties in paddy fields and coconut plantations. *Coleus amboinicus* Lour. Acts as an deterrant against *Oryctes rhinoceros* (Scarabaedae: Coleoptera) beetles and prevent the insect from laying eggs on coconut plants especially in nurseries. So around coconut plantations in nursery it is necessary to plant certain *Coleus aromaticus* plants around coconut seedlings.

Conclusion and future perspectives

Indian farming, which is dynamic in nature, will slowly but surely adopt different pest management through using indigenous technical knowledge for sustainable agriculture[25]. Adoption of ITK based crop protection measures can be an alternative to pesticides and this might help in restoring the biodiversity of natural enemies, thus it can shape the tritrophic interaction properly but as a knowledge-based and farmer driven approach, preliminary education to farmers should be given to utilise the IPM related control measures effectively. Sustainable crop production and protection can be achieved by creating easily acceptable and cost-effective technologies and processes, and at this time, ITK connected to plant protection in agriculture will play an important role and will gain popularity over chemical control. An endeavour to produce Indigenous Technical Knowledge (ITK)-based goods on a small and big scale is an economically viable option for sustainable agricultural production. The National Innovation Foundation (NIF) and the Government of India's Department of Science and Technology have also encouraged traditional knowledge-based innovations. As a result, in this context, the need for ITK is critical in order to appropriately blend these ITKs with scientific knowledge related to pest management strategy in agriculture for better controlling and minimising pest attacks on crops and thus making agriculture more productive and profitable for farmers.

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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 **25** years of experience in Research and Extension Education Works. **He authored many books** such as Plant Breeding, Agriculture at a Glance, Hand Book of Agricultural Sciences (Hindi & English), 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 Journal** (both Journals are NAAS recognized), **Secretary,** Society for Scientific Development in Agriculture & Technology and also **President,** 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)**.

Glimpse of SSDAT & Astha Foundation's Conferences

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